AFFIDAVIT OF GARY J. FOWLER, PH.D

STATE OF CALIFORNIA)
) ss.
COUNTY OF LOS ANGELES)

I, Gary J. Fowler, Ph.D., being first duly sworn upon oath, depose and state:

1. I am a metallurgical and failure analysis expert. I was asked by Airbus Helicopters to evaluate damage to components from the engine, drive trains, and rotor systems on an AS350 B2 helicopter, S/N 3158, operated by ERA Helicopters, Inc., that was involved in an accident on April 15, 2008 near Chickaloon, Alaska. This accident was the subject of NTSB Accident ID ANC08FA053.

2. I possess personal knowledge of the matters set forth herein, and if called upon as a witness in this action I could competently testify to them.

3. Attached hereto as **Exhibit A** is a true and correct copy of my report entitled *Analysis of Damage to a Eurocopter AS350-B2 Helicopter NTSB ID ANC08FA053*, which contains my findings, conclusions and opinions from my evaluation of damage to this helicopter.

I declare under penalty of perjury that the foregoing is true and correct.

Executed at Gardena, California, on July 2, 2014.

[redacted]
Gary J. Fowler, Ph.D

STATE OF CALIFORNIA)
) ss.
COUNTY OF LOS ANGELES)

Subscribed and sworn to before me this _____ day of July, 2014.

STATE OF CALIFORNIA
COUNTY OF LOS ANGELES
Subscribed and sworn to (or affirmed) before me this 02ND day of July, 2014
by Gary J. Fowler
proved to me on the basis of satisfactory evidence to be the person(~~s~~) who appeared before me.

JOHN K. CHO
COMM. #1929298
Notary Public - California
LOS ANGELES COUNTY
My Comm. Exp. Mar. 24, 2015
BCT 4

____
Notary Public

FOWLER INC.

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ANALYSIS OF DAMAGE TO A EUROCOPTER AS350-B2 HELICOPTER
NTSB ID ANC08FA053

Aircraft:	**Eurocopter AS 350-B2, S/N 3158**
Registration:	**N213EH**
Date:	**April 15, 2008**
Location:	**Sheep Mountain, Alaska**
Operator:	**ERA Helicopters Inc.**
NTSB ID:	**ANC08FA053**

Prepared For: **Airbus Helicopters**

Prepared By: **Gary J. Fowler, Ph.D.**

July 2, 2014

ANALYSIS OF DAMAGE TO A EUROCOPTER AS350-B2 HELICOPTER

INTRODUCTION

An evaluation of damage to components from the engine, drive trains, and rotor systems on an AS350-B2 helicopter was conducted to determine the cause and sequence of damage. The helicopter was involved in an accident on April 15, 2008 near Sheep Mountain, Alaska. According to the National Transportation Safety Board (NTSB) Factual Report, the helicopter was operated by ERA Helicopters during a cross-country passenger flight to shuttle telecommunications technicians and equipment between remote sites near Chickaloon, Alaska. On the morning of the accident, the helicopter departed from a roadside rest area along Alaska State Highway 1 in light snow. A motorist driving on the highway about one mile to the south observed the helicopter flying below the overcast prior to a steep descending right turn toward the ground. The helicopter impacted on a steep embankment of a ravine about three-quarters of a mile east of the departure point and at a lower elevation of approximately 400 ft. The embankment was reported to have an incline of approximately 35 to 50 degrees, and was covered with willow brush, and 3 to 5 feet of snow.

Figure 1 shows an aerial view of the helicopter at the accident site below the ridge of the ravine. The helicopter impacted the sloping terrain with a substantial vertical descent and remained in a level attitude. The fuselage damage from the impact was mostly on the right side. The right skid separated from the helicopter and was located on the down sloping terrain to the left of the helicopter. The left skid was partially suspended in air away from the slope (Figure 2). Small trees adjacent to the left side of the helicopter were broken indicating some movement to the right during the impact with the slope. The main gearbox (transmission) was tilted toward the slope. The forward end of the tail boom was buckled in a downward direction indicating a substantial vertical descent during ground impact (Figures 2 and 3). The blue main rotor blade exhibited damage on the trailing edge during the vertical descent through the brush (Figure 4). The willow brush around the helicopter at the crash site was not cut by the main rotor blades indicating lack of significant rotor speed during ground impact (Figures 4 and 5). The tail rotor blades mostly were covered with snow (Figure 6).

The helicopter was transported to a hanger in Anchorage, Alaska and examined by the NTSB, American Eurocopter, and Turbomeca. Photographs of the helicopter were provided for review and were date stamped April 24 or 25, 2008. Figure 7 shows the cabin area and the crushing on the right lower side. Photographs of the main rotor head show that the yellow star arm was fractured on a diagonal plane and that the blue and red sleeves were partially shattered (Figure 8). The main rotor blades exhibited leading edge impact damage and chordwise abrasions. Figure 9 shows the cabin interior and the location of the floor mounted engine controls. The center console adjacent to the floor controls was displaced to the right. A closer view of the floor mounted controls is shown in Figure 10. The fuel flow control lever (yellow handle) was out of the flight detent position and partially rotated down toward the emergency position. The fuel cut-off lever was in the off position. The rotor brake was in the stowed position.

The purpose of the evaluation was to determine the cause for and sequence of damage to the helicopter during the events that occurred on the morning of the accident. After the accident when the helicopter was examined in Anchorage, the floor mounted fuel flow control lever (FFCL) was found to be out of the flight detent and rotated down in the direction of the emergency position. The evaluation also considered causes for movement of the FFCL and the effect of moving the lever during flight into the emergency position. Appendix A lists items received for review consisting of accident investigation reports, scene and helicopter wreckage photographs, deposition testimony, and component illustrations.

EUROCOPTER AS350 HELICOPTER

The AS350-B2 helicopter is powered by a Turbomeca Arriel 1D1 turboshaft gas turbine engine. Figure 11 shows an illustration of the engine modules. During engine operation, air enters the compressor (Module No. 2) and is compressed by an axial rotor and centrifugal impeller. Compressed air enters the combustion chamber where it mixes with fuel and is ignited. The hot expanding combustion gases drive the compressor turbine (CT) wheels and the power turbine (PT) wheel. The CT wheels, also referred to as the gas generator turbine wheels, provide power to the engine compressor. The PT wheel, also referred to as the free turbine, provides rotation energy to the gearbox (Module No. 5) which is transmitted forward through the engine power shaft assembly (Module No. 1) to the main gear box (MGB) to drive the main rotor (MR) and rearward to the tail rotor (TR)(Figure 12). Figure 13 shows an illustration of the driveshaft between the engine and the input pinion in the MGB. The driveshaft is a steel tube with a flange at each end to which a flex coupling attaches. Output from the engine gearbox also drives the TR driveshaft, gearbox, and blades (Figure 14). The TR driveshaft consists of a forward steel shaft and a longer aft aluminum shaft (Figure 15). The forward steel shaft is connected to the tail rotor output of the engine power shaft assembly (Module No. 1). The aft end of the steel shaft engages with a splined steel adapter attached to the aluminum shaft.

HELICOPTER EXAMINATION

An examination of helicopter components was conducted on September 11, 2012 at a storage facility in Wasilla, Alaska. Figure 16 shows an overall view of the helicopter cabin. The forward end of the tail boom adjacent to the fuselage was buckled due to downward forces during the collision at the crash site (Figure 17). The aft end of the tail boom, including the tail rotor gearbox, was separated due to tearing of the boom (Figure 18). The engine, MGB, and MR head were not with the wreckage in Wasilla, Alaska. The MGB was examined previously and found to rotate freely. The MGB components were in good condition. The FFCL and housing panel were removed previously and stored in a separate box. The engine, MGB, and MR head were examined on October 24, 2012 at Air Salvage of Dallas (ASOD), Lancaster, Texas. An exemplar helicopter and a MR head were examined on October 24, 2012 at American Eurocopter, Grand Prairie, Texas. An examination of the CT wheels, spline coupling between Module No. 4 and No. 5 ("muff" coupling), and main rotor drive coupling were examined at SEAL Labs, El Segundo, California on October 31, 2012. Following is a description of component damage:

Main Rotor Blades

The AS350 helicopter has three main rotor blades that are color coded red, yellow, and blue. When viewed from above the blades rotate in a clockwise direction. Figures 19 and 20 show the MR blades during the inspection on September 11, 2012. All three blades exhibited impact damage to the leading edge, skin tearing, buckling, and separation (splitting) at the trailing edge (Figure 21). The outboard end of the red blade exhibited chordwise bending and was shattered. The abrasion strip was deformed and the tracking finger separated (Figures 22 and 23). The stainless steel leading edge abrasion strip exhibited multiple dents and chordwise abrasions caused by impact with the terrain while the blade was rotating at a significant speed. The yellow blade also exhibited chordwise bending, leading edge dents, and chordwise abrasions (Figures 24 and 25). The blue blade exhibited damage similar to the red blade but to a lesser extent (Figures 26 and 27). All three blades exhibited damage caused by impact with the terrain while at a significant rotational speed. This damage occurred prior to the final impact at the crash site as indicated by the lack of rotor speed when the helicopter impacted the sloping terrain.

MGB and Main Rotor Head

The MGB and MR head assembly were examined at ASOD. The input pinion for the MGB was rotated by hand, which caused the planet gears to rotate. There was not any indication of binding or a malfunction in the MGB. Figure 28 shows an illustration of the MR head components. Figure 29 shows the head components from the accident helicopter. The yellow star arm was fractured on a diagonal plane (Figure 30) indicating impact of the blade during powered rotation. The blue sleeves were shattered (Figure 31). The blue star arm was cut. The yellow and red sleeves were split. Damage to the head components indicates that the blades impacted the terrain while under power transferring the forces to the head and causing the damage to the star arm and sleeves.

Engine-To-MGB Driveshaft

Figure 13 shows an illustration of the driveshaft between the engine and MGB. Power produced by the engine provides rotational torque to the driveshaft and MGB. Rotational power is transferred to the driveshaft through a spline connection (engine shaft flange, Figure 13). The shaft is connected to the MGB input pinion through a flex coupling at the forward end. Figure 32 shows the driveshaft between the engine and MGB during the September 11, 2012 inspection. The flex couplings at both ends were intact. The shaft has a rotational twist and partial fracture (Figure 33). Engineering analysis performed by Eurocopter indicates that torsional deformation to the shaft requires an overload torque in excess of 300 percent. The driveshaft rotates clockwise when viewed from the engine. The direction of twist (torsional buckles) in the driveshaft indicates that the engine was driving the shaft when the forward end at the MGB encountered a severe resistance. The severe resistance caused the engine to overload the driveshaft resulting in torsional deformation. The severe resistance was produced during impact of the MR blades with the terrain. Impact of the MR blades with terrain occurred prior to the final crash site impact and caused a substantial resistance to rotation of the blades and MGB. The engine was providing rotational power to the driveshaft at the aft end while the forward end was encountering substantial resistance during MR blade impact. The result was a twisted shaft. The twisting deformation caused the overall length of the driveshaft to shorten. The measured length of the twisted shaft was 32.2 cm, compared to the manufactured length of 34.1 cm. Shortening of the shaft by approximately 1.9 cm caused the spline coupling at the aft end of the driveshaft (Figures 34 and 35) to nearly separate from the mating splines on the power shaft assembly (Figure 36). An overlap of approximately 3.5 mm existed between the mating splines. Continued rotation of the engine power shaft caused rotational smearing at the ends of the mating splines (Figures 35 and 36) and disengagement of the driveshaft. The splines on the coupling for the engine power shaft assembly and on the driveshaft spline coupling were both damaged resulting in loss of drive to the MGB and MR blades. The coupling tube surrounding the driveshaft exhibited a small area of deformation.

Tail Boom

Accident scene photographs show downward deformation at the forward end of the tail boom and tearing of the tail boom aft of the horizontal stabilizer. Figure 17 shows the tail boom during the inspection. The end of the right horizontal stabilizer was crushed during impact with the sloping terrain. The right side of the boom and TR driveshaft cowling exhibited deformation and embedded wood from impact with a tree (Figures 37, 38 and 39). A small broken tree was located adjacent to the left side of the tail boom near the deformed area. The TR driveshaft and cowling were not impacted by a rotating MR blade during the vertical descent at the final crash site, further indicating lack of significant rotor speed.

Tail Rotor Driveshaft

Figures 14 and 15 show illustrations of the TR driveshaft. Rotational power from the engine is transferred to the gearbox (Module No. 5) and the engine power shaft assembly (Module No. 1). The power shaft is connected to the TR driveshaft. The TR driveshaft is located on the top of the tail boom and is covered with a sheet metal cowling. Figure 40 shows the tail boom with the driveshaft cowling (painted black) in place. The forward end of the tail boom was severely buckled due to the downward collision forces. The downward deflection caused the TR driveshaft to separate at the spline connection at the aft end of the steel section of the driveshaft.

Figure 41 shows the forward (steel) segment of the TR driveshaft after being repositioned on the tail boom. The flex coupling at the forward end of the steel shaft (Figure 42) connects to the engine TR drive output. The flex coupling was fractured due to overload forces. The aft end of the steel driveshaft is shown in Figure 43. The flex coupling and splines are intact. The outer edges of the aft flex coupling exhibit light deformation from contact during rotation with the TR driveshaft cowling (Figure 44). Mating rotational scoring was present on the inner surface of the cowling (Figure 45). The rotational damage indicates that the TR driveshaft had some residual rotation during impact with the terrain at the final crash site. The vertical impact forces caused the tail boom to deform downward and the steel section of the driveshaft to separate at the spline connection with the aluminum shaft. Continued rotation of the driveshaft caused the rotational damage to the flex coupling and cowling. The forward flex coupling fractured due to overload forces after separation at the spline connection and deflection of the driveshaft.

Tail Rotor Blades, Gearbox, and Hub

Figure 46 shows the TR blades adjacent to the aft section of the tail boom. The fiberglass in both blades was shattered due to impact forces. The strike tabs on both blades were bent opposite to the direction of rotation (Figures 47 and 48). The leading edge abrasion strip on one blade was dented due to contact with the terrain during blade rotation (Figure 47). Both blades exhibit chordwise abrasions. The blades also exhibit contact marks from flapping.

The tail rotor gearbox rotated freely. The aluminum driveshaft and pitch control tube were cut previously. The TR hub is installed on the gearbox output shaft and secured with a bolt and key (Figure 49). The key between the output shaft and hub had sheared due to overload forces (Figures 50 and 51). The output shaft rotates counter-clockwise when viewed from the end of the shaft. The direction of shear on the fractured key was opposite to the direction of shaft rotation. Either there was a significant acceleration of the output shaft caused by suddenly available engine power when the MR blades contacted the ground and the engine-to-MGB driveshaft separated, or the TR blades impacted the ground at the same time as the MR blades during the initial ground contact. Damage to the output shaft key most likely occurred prior to the final ground impact at the accident site that caused boom deformation, separation of the TR driveshaft, and blade damage.

Fuel System Controls

Figure 52 shows an illustration of the floor mounted controls, including the fuel flow control lever, and linkage to the engine. The FFCL has three positions – "stop" (off) and start, "flight," and "emergency" position. The emergency position is below the flight position and allows for manual control of the fuel flow. Following the accident the FFCL was observed to be out of the flight detent and rotated down (forward) toward the emergency position (Figure 10). In order to shift the FFCL from the flight detent to the emergency position, the lever must be moved laterally 0.4 in. to the right, then rotated down 0.7 in. After the accident the FFCL was found to be out of the flight detent and rotated down (forward) approximately 0.3 in. The emergency fuel shutoff lever was found in the full aft detent (off) position. The wire securing the shutoff lever in the forward position was broken. The FFCL and housing panel were removed after the accident. Figures 53 and 54 show the cockpit floor where the levers were installed. Figure 55 shows the components stored in a separate box. Slight wear marks were present on the side of the lever from contact with the cover slot during use. The lower end of the FFCL was disconnected previously from the linkage. Figure 56 shows the linkages for the three levers under the cockpit floor. Continuity of the FFCL linkage was checked back to the engine (Figure 57). The rod was bent adjacent to the fitting. The cable could be moved manually when the fitting that attaches to the FFCL was pushed rearward and forward. Cable movement was limited by the bend in the rod.

ENGINE EXAMINATIONS

The engine was partially disassembled and examined previously by Turbomeca during the NTSB investigation. The blades on the PT wheel were broken adjacent to the fir tree section that engages with the disk. According to Turbomeca, PT blade shedding occurs by design when the engine speed exceeds approximately 150% NF (free turbine or PT speed) or 62,374 RPM. The fuel control unit (FCU) was bench tested after the accident and performed normally. Rotational drive from the PT wheel is transmitted to the engine gearbox (Module No. 5) through a spline coupling ("muff" coupling) and the drive retaining nut. After assembly and tightening of the nut, index marks are vibropeened into the nut and adjacent surface. The nut can be over torqued if the engine is producing power and severe resistance to rotation is encountered such as would occur during impact of the MR blades or component failure in the MGB. The MGB did not fail.

Additional Engine Examination

The engine was further disassembled at ASOD and examined on October 24, 2012. Figure 58 shows the PT wheel, muff coupling, and module No. 5 gearbox. Figure 59 shows the PT disk and blade root segments. Fracture of the blades occurred due to overload forces caused by engine over speed. Multiple impacts were present on the PT containment ring and exhaust duct due to shedding of the blades. The drive retaining nut was over rotated by approximately 7 mm as indicated by the misaligned index marks (Figure 60). Over rotation of the nut occurred when the MR blades impacted the terrain prior to the final crash site causing a severe resistance to rotation. The engine power provided the necessary overload torque required to over rotate the nut during MR blade impact. Impact of the MR blades also caused the muff coupling between the PT wheel and input to the gearbox to deform outward and developed cracks at both ends (Figure 61). The outward flare caused partial loss of spline engagement and eventual damage to the coupling splines (Figure 62) and the PT shaft splines (Figure 63). The same MR blade impacts that caused the engine-to-MGB driveshaft to deform due to overload torsional forces also caused the drive retaining nut to over tighten and the muff coupling to deform. The engine had to have been producing substantial power in order to cause this damage. Engine over speed occurred when the load from the MGB and MR blades was eliminated due to disengagement of the engine-to-MGB driveshaft. Torsional deformation to the PT nozzle housing (bearing support assembly) also is consistent with a severe torque due to MR blade strike. These damage areas had to occur prior to the shedding of the PT blades, which would cause loss of rotational power to the gearbox. If the FFCL was moved initially during flight to the forward emergency position with a functioning FCU, engine over speed and blade shedding would not have occurred because the rotors would have been loaded.

Figures 64 and 65 show the first and second stage CT gas generator wheels, respectively. The blades did not exhibit evidence of overheating. Metal splatters were on the inlet nozzle vanes (Figure 66) and CT wheels (Figure 67). The metal splatters occurred due to rubbing of the compressor axial blades and impeller (Figure 68) during engine operation, most likely when the PT wheel lost its blades. The CT wheels also exhibited minor blade tip rub.

Comparison with AS350B accident near Blanding, Utah

Eurocopter identified an accident that occurred on May 4, 2000 near Blanding, Utah (NTSB ID: DEN00FA085) involving an AS350B helicopter and intentional movement of the FFCL to the emergency position during flight. The NTSB determined that the probable cause of the accident was the "pilot's loss of aircraft control due to abrupt maneuvering" in a high density weather condition. After the accident, the manual throttle position on the FCU was found to be in the emergency position. The NTSB determined that a contributing cause to the accident was "the pilot manually introducing excessive fuel into the engine." The helicopter did not exhibit over torque conditions of the engine to the MGB and the engine to tail rotor gearbox. The MR blades exhibited light abrasions. The first and second stage CT wheel blades were missing 50 to 70 percent of the blades due to melting (Figures 69 and 70). The PT wheel did not shed its blades. The absence of torsional damage to the drive train components, melting of turbine wheel blades, and lack of shedding of the PT blades are characteristics of the

Blanding, Utah accident that occurred when the FFCL was moved to the emergency position in-flight. The difference in damage patterns between the Utah accident and the subject accident in Alaska further indicates that the FFCL was not moved into the emergency position during flight in the subject accident.

DISCUSSION

After liftoff from the roadside rest area, the helicopter descended to a lower elevation and impacted steep terrain covered with snow and willow brush. The helicopter impacted the terrain during a vertical descent and remained in a level attitude at the crash site. Damage to the cabin was mostly on the right side. The willow brush surrounding the helicopter was not cut, indicating the lack of significant MR blade rotation when the helicopter impacted the steep slope at the final crash site. The helicopter MR blades and hub components exhibit damage caused during blade impact with the terrain while rotating under power. The engine-to-MGB driveshaft, TR driveshaft key, muff coupling, and Module No. 5 drive retaining nut exhibit torsional overload damage caused by impact with the rotor blades while the engine was producing power. This could only have occurred if the rotor blades impacted the terrain prior to the final impact at the crash site.

Loss of drive to the MR blades occurred due to the torsional deformation to the engine-to-MGB driveshaft. The driveshaft deformation occurred due to impact of the main rotor blades with terrain while being driven by the engine. The driveshaft deformation must have occurred after departure and near the crash site in order to lose MR blade rotation at the final crash site. Impact of the MR blades also caused deformation to the muff coupling and over rotation of the drive retaining nut. Loss of the driveshaft to the MGB caused the engine to over speed and resulted in shedding of the PT blades. The engine was not likely to have been running under any power at the crash site. Downward deformation of the boom caused the TR driveshaft to decouple at the aft end of the forward steel shaft. Continued residual rotation of the steel shaft segment connected to the engine power shaft caused rotational damage to the driveshaft coupling and inner surface of the cowling.

The NTSB found that that an in-flight loss of power occurred; however, the power loss was attributed to an unintentional movement of the FFCL during flight to the emergency position. According to the NTSB Factual Report and Probable Cause Determination, the forward movement of the FFCL allegedly caused an engine over speed that resulted in the torsional deformation to the engine-to-MGB driveshaft and shedding of the PT blades. This explanation for the accident is not supported by the following technical evidence:

- The main driveshaft requires an applied torque in excess of 300% to cause torsional deformation. Analysis by Eurocopter and information provided by

Turbomeca indicate that the maximum torque supplied by the forward movement of the FFCL during flight is 170-200%. The torsional deformation in this accident only could have occurred due to impact of the main rotor blades with terrain while the engine was producing power prior to the final crash site.

- The engine drive retaining nut in Module No. 5 was over rotated by 7 mm due to an excessive applied torque (estimated to be 500%) while the engine was running. The PT can apply the excessive torque only if the MR blades impact the terrain causing substantial resistance to rotation. Similarly, deformation to the muff coupling indicates that excessive torque was applied to the nut during MR blade impact with the terrain.

- In order to move the FFCL from the flight detent to the emergency position, the lever must be moved initially to the right and then rotated down (forward). When the helicopter impacted the sloping terrain, there was a displacement of the MGB and the center console adjacent to the floor controls to the right. Impact on the right lower side of the fuselage and skid caused inertia forces on the helicopter and occupants to the right and down. The FFCL is angled forward when in the flight detent position. Collision force is the most probable explanation for movement of the FFCL initially to the right and then down slightly.

- Movement of the FFCL to the emergency position during flight would not cause shedding of the PT blades. Even assuming (incorrectly) that it does, the engine would lose rotational power to the gearbox and would not be able to twist the engine-to-MGB driveshaft, over rotate the Module No. 5 drive retaining nut, or deform the muff coupling.

- The only known event to cause shedding of the PT blades consistent with the physical evidence is loss of the drive connection from the engine to the MGB.

The NTSB's January 19, 2012, response to Petition for Reconsideration appears to acknowledge that the torsional deformation to the engine-to-MGB driveshaft could not have occurred in flight as a response to a FFCL movement into the emergency position. Instead, the NTSB now asserts that the torsional damage occurred during final ground impact. This explanation is not supported by the following technical evidence:

1. All three main rotor blades exhibit damage caused during impact with the terrain while at significant rotational speed (Figures 19 through 27). This damage occurred prior to final impact at the crash site as indicated by the lack of rotational damage to the willow brush surrounding the helicopter at the final resting place (Figures 2 through 6).

2. The twisted engine-to-MGB driveshaft (Figure 32), over-rotated module No. 5 drive retaining nut (Figure 60), and deformed muff coupling (Figure 61) all indicate significant engine power applied to the engine gearbox and driveshaft when a substantial resistance was encountered. Damage to the main rotor blades is the only indication of a substantial resistance that would explain the shaft and coupling deformation and nut over-rotation. The main rotor damage occurred during flight and prior to the final crash site.

3. Disengagement of the engine-to-MGB driveshaft occurred due to shortening of the shaft during the torsional deformation. Sudden removal of the load caused the engine to overspeed and shedding of the PT blades. Without the PT blades, the engine rapidly loses power and rotational speed (RPM). The energy of the rotating PT disk is proportional to the square of the RPM, resulting in a rapid exponential decline in rotational energy available to cause an applied torque to the driveshaft. Therefore, it is not reasonable to conclude that residual rotation of the PT wheel after blade shedding could cause the torsional deformation to the driveshaft.

After the accident the FFCL was found out of the flight detent and rotated down (forward) approximately 0.3 in. A movement to the right of 0.4 in. is required to take the FFCL out of the flight detent. Collision damage to the helicopter indicates more severe impact forces on the right side. The center console and MGB were displaced to the right and indicate the direction of inertia forces during the impact. The tail boom further indicates significant downward forces. Movement of the FFCL 0.4 in. to the right and 0.3 in. rotated down likely occurred due to movement of the lever during the collision with the terrain. The position of the FFCL after the accident, as documented in Anchorage after removal of the wreckage from the crash site, is consistent with the direction of collision forces. The FFCL was not in the emergency position prior to the collision with the terrain. The damage to the rotors, engine, and drive trains is not consistent with movement of the FFCL to the emergency position during flight.

CONCLUSIONS

Numerous findings and opinions have been expressed in this report. The opinions are based on information reviewed, examinations conducted, education, and experience from over thirty-five years of analyzing components from gas turbine engines and helicopters involved in accidents. Opinions are expressed to a reasonable degree of engineering certainty. Following is a list of general opinions.

1. Damage to the helicopter engine-to-MGB driveshaft and main rotor blades indicate that the blades impacted the snow covered terrain during flight prior to the final crash site. The main rotor blades did not have significant rotor speed when the helicopter impacted the terrain at the final crash site.

2. Torsional deformation to the driveshaft between the engine and MGB was caused by excessive torsional forces during impact of the main rotor blades with the terrain during the flight and prior to the final crash site. Blade impact caused a resistance to rotation while the engine was producing significant power, which caused a torsional overload of the driveshaft.

3. Over rotation of the Module No. 5 drive retaining nut and deformation of the muff coupling also indicate that the engine was producing significant power when the main rotor blades impacted the terrain in flight.

4. Torsional deformation and resultant shortening of the main driveshaft caused the aft end of the driveshaft to disengage from the engine power shaft assembly. The result was a loss of drive to the MGB and main rotor blades and engine overspeed that caused shedding of the PT blades.

5. The tail rotor blades were being driven by the engine when impact with the snow covered terrain occurred during the flight and prior to the impact at the final crash site. The strike tabs were deformed opposite to the direction of rotation and one blade had a leading edge dent. The output shaft key was sheared due to overload forces. These overload forces were either caused by the sudden engine overspeed which occurred as a result of the in-flight main rotor blade strike and driveshaft separation, or a tail rotor blade strike at the same time as the MR blade strike.

6. The disengagement of the driveshaft between the engine output and the MGB caused the engine to over speed, resulting in shedding of the power turbine blades and loss of engine power.

7. There was an absence of engine power and insufficient main rotor RPM at the time of the final crash impact to have caused the torsional deformation to the driveshaft, over-rotation of the module No. 5 gearbox nut, and deformation to the muff coupling.

8. The vertical impact forces at the crash site caused the tail boom to deform downward. The tail boom deflection caused the tail rotor driveshaft to separate at the spline connection between the steel shaft and aluminum shaft. Continued residual rotation of the forward (steel) segment of the TR driveshaft caused rotational damage to the aft flex coupling and TR driveshaft cowling.

9. Movement of the fuel flow control lever in flight is not consistent with damage to the helicopter and engine components. Inadvertent movement of the FFCL to the emergency position during flight would not twist the main driveshaft, over rotate the engine drive retaining nut, deform the muff coupling, shear the TR hub/output shaft key, or over speed the PT wheel. It would also cause extensive

heat damage to the first and second stage CT blades as occurred in the Blanding, UT accident. The CT blades from the subject accident engine did not exhibit heat damage.

10. The position of the FFCL observed after the accident is consistent with the direction of collision forces and most probably was displaced to that position during impact with the slope.

11. The location and sequence of physical damage to the rotor blades, engine, and drive trains indicate that the accident was caused by impact of the main rotor blades with the terrain during the flight prior to a loss of power and final impact on the sloping terrain at the crash site.

12. There was not any evidence of a metallurgical or manufacturing defect in the helicopter or any of the components.

Best regards,

[redacted]

Gary J. Fowler, Ph.D.

/4553

Figure 1

Figure 2


Helicopter At Accident Site

Figure 3


Helicopter At Accident Site

Figure 4

Figure 5

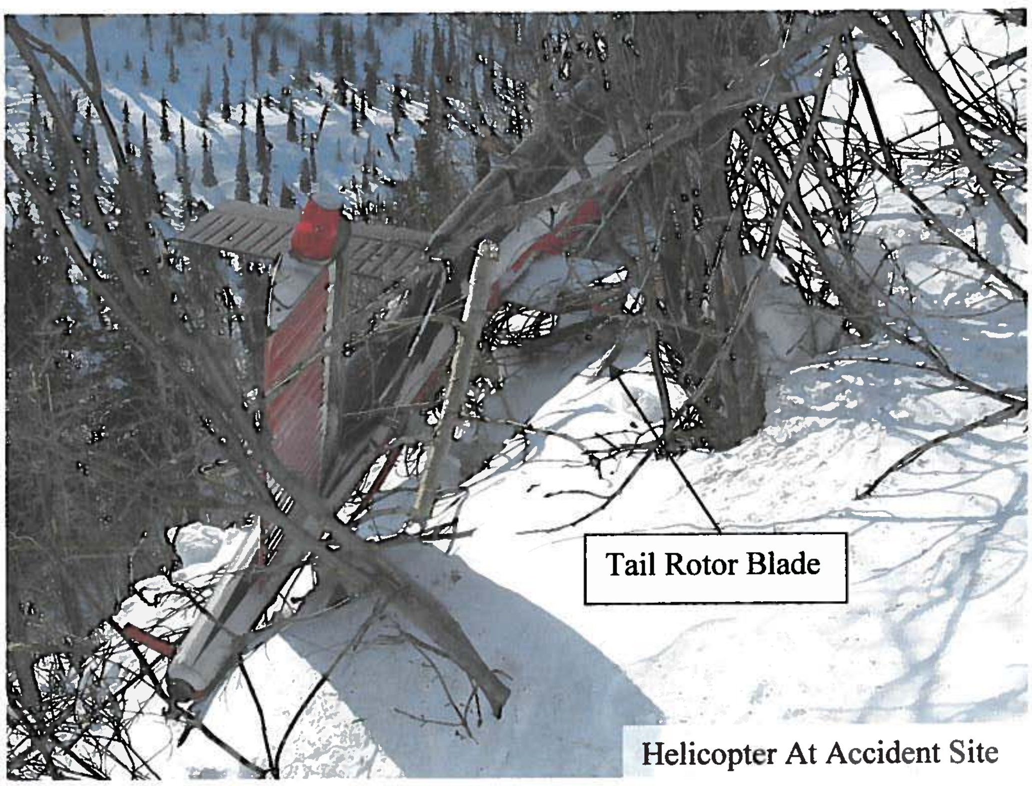


Figure 6

Figure 7

Figure 8

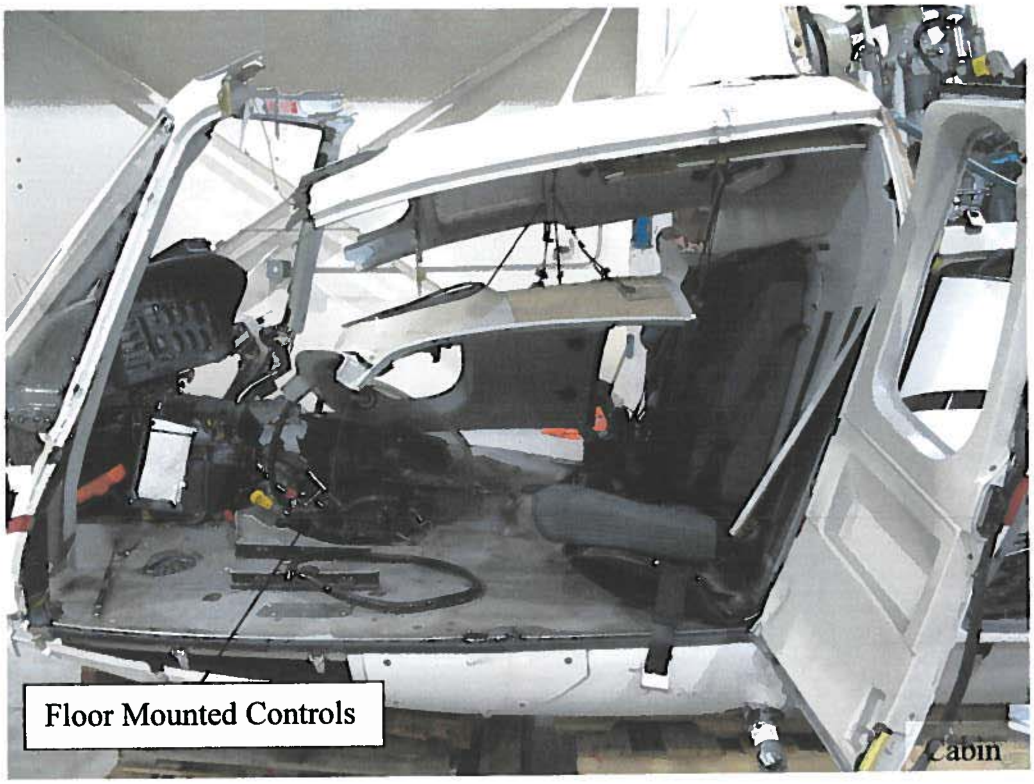


Figure 9

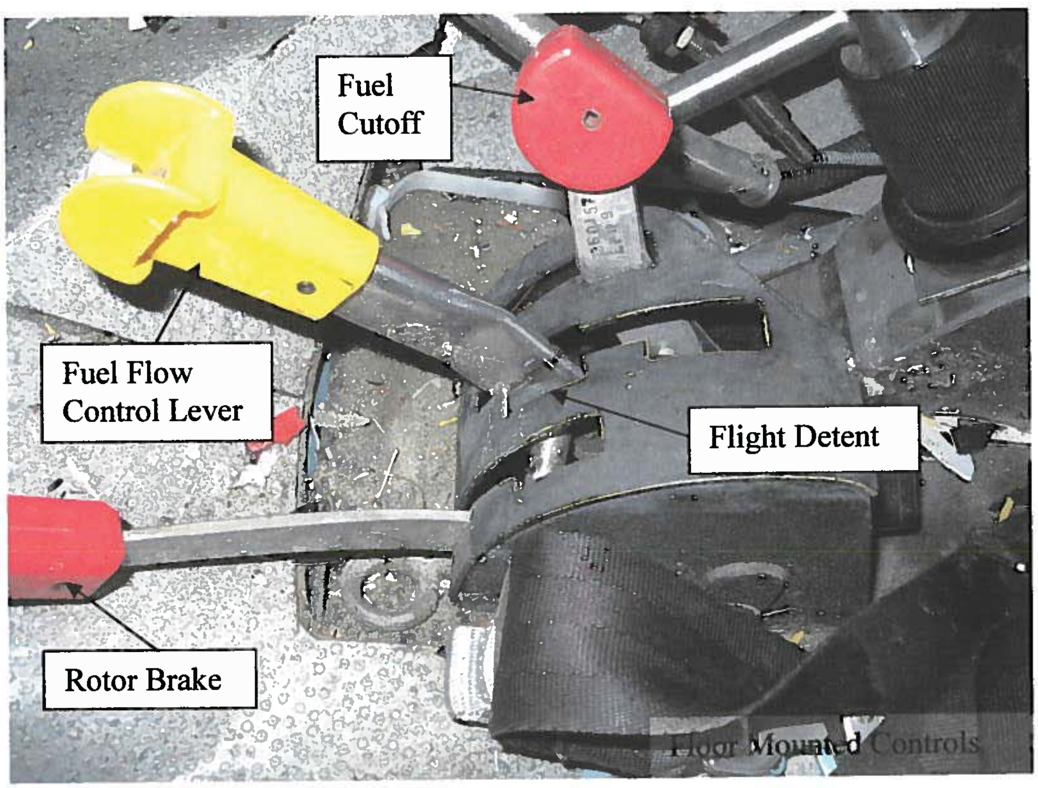


Figure 10

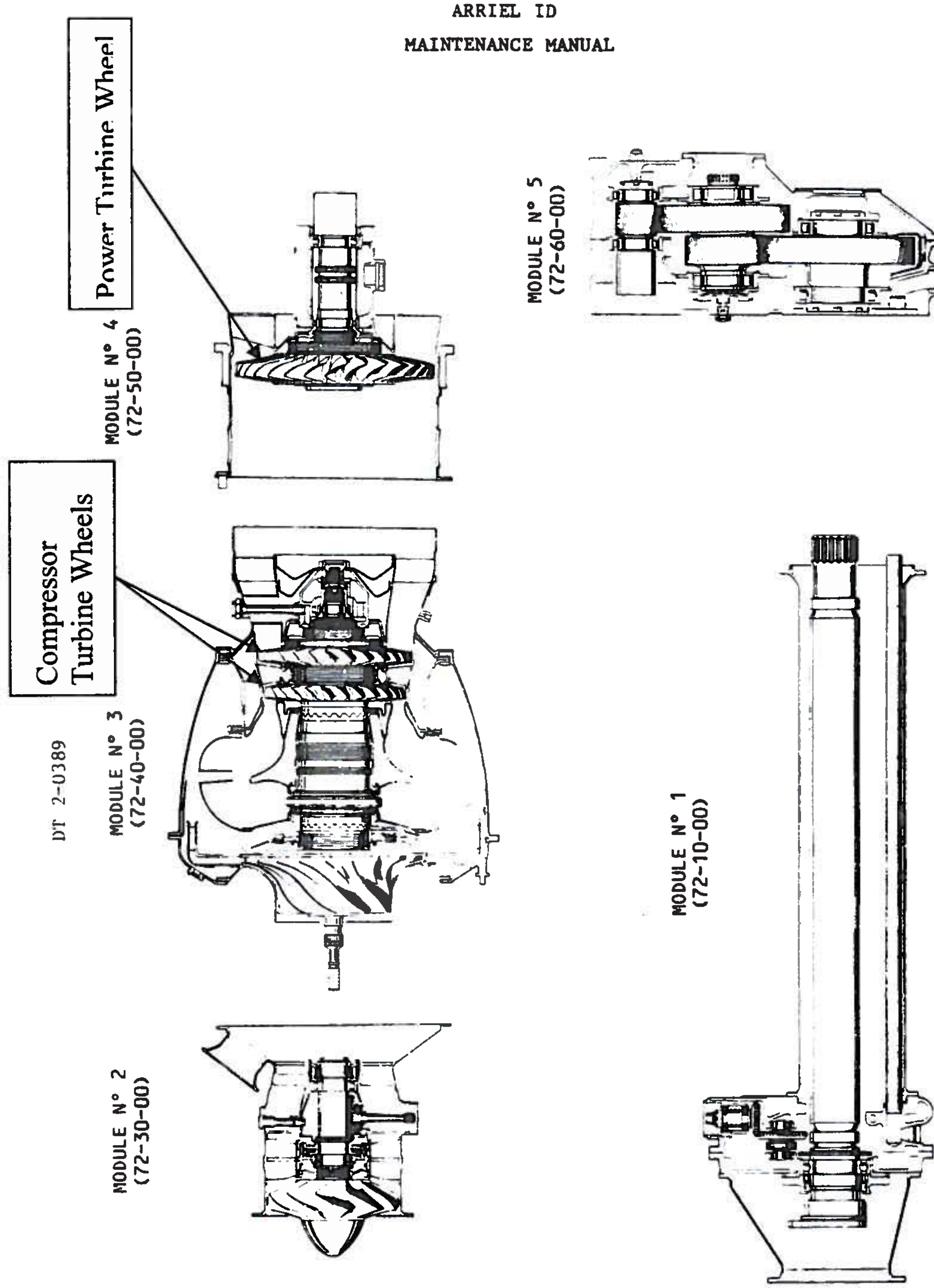


Figure 3 - Modular design

Figure 11

3.3 - ENGINE/MGB COUPLING

The engine/MGB coupling comprises:

- a casing (1) secured to the MGB and a flanged connecting coupling (3) secured to the engine.
- a gimbal ring (2) joining the casing and flanged coupling.
- the drive shaft (4) transmitting the engine torque to the MGB via the input pinion.

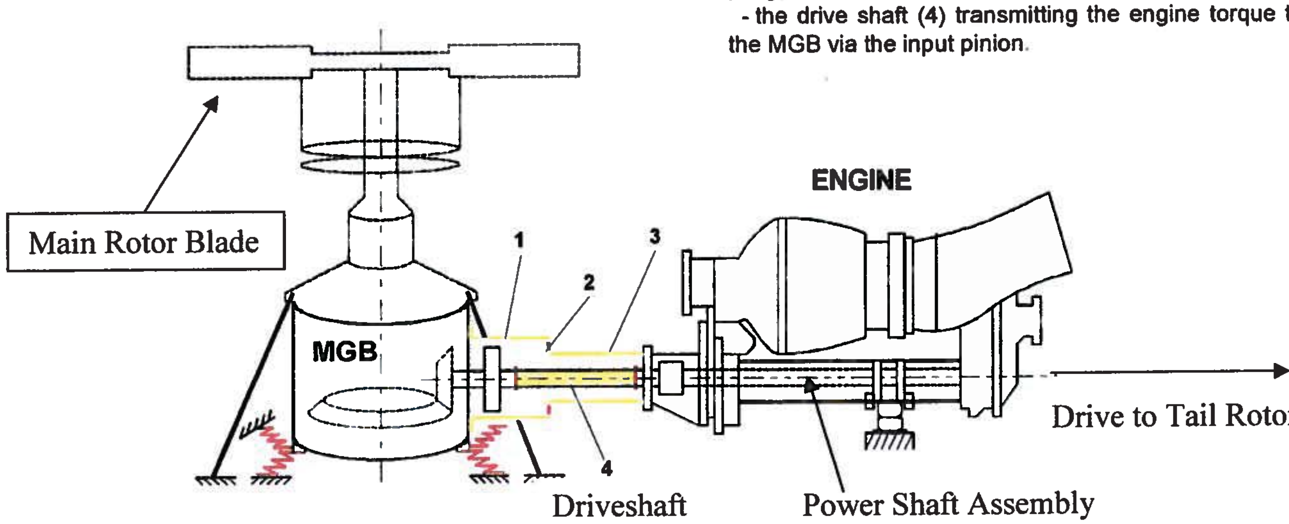


Figure 12

3.3.1. ENGINE/MGB COUPLING COMPONENTS

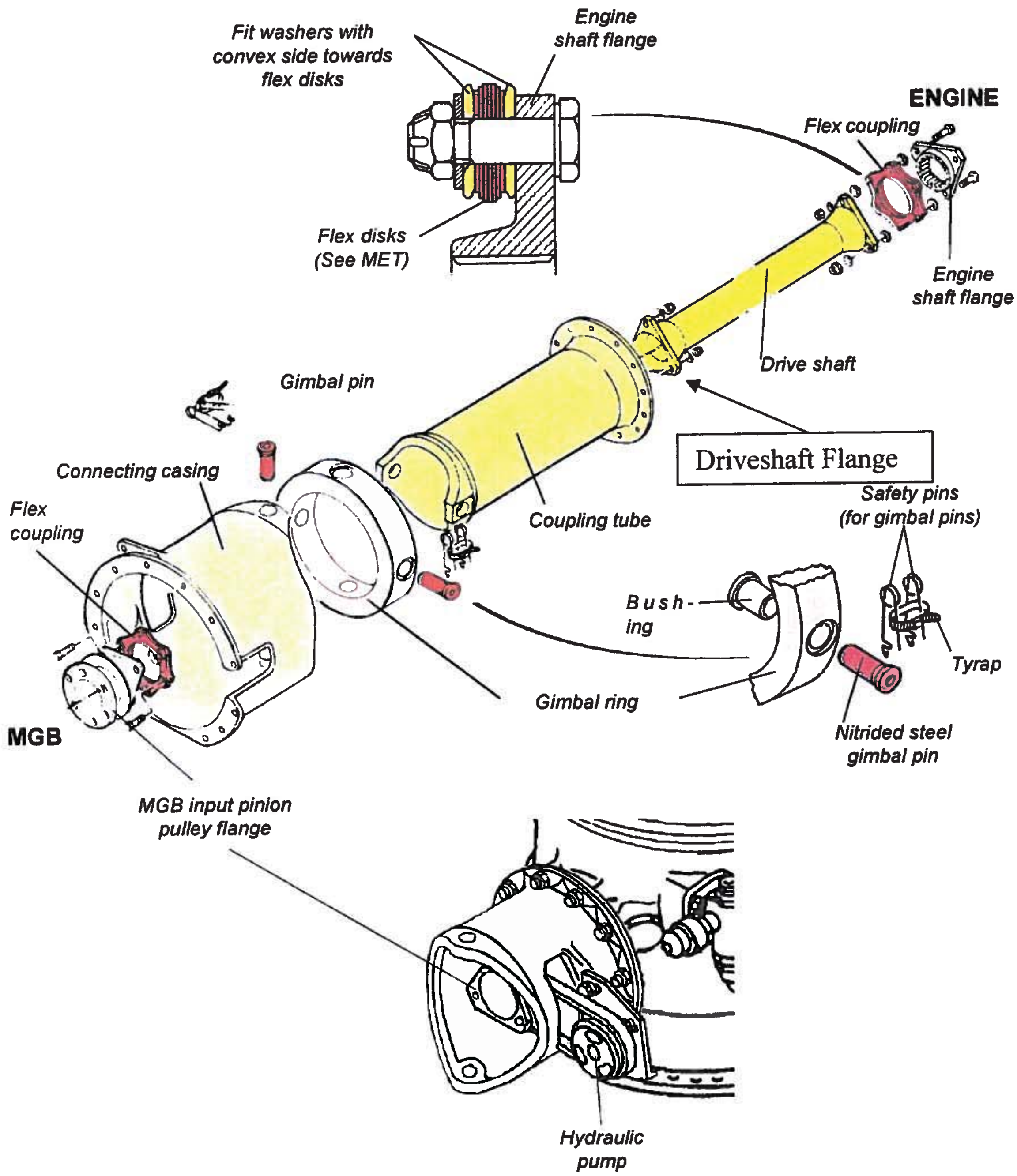
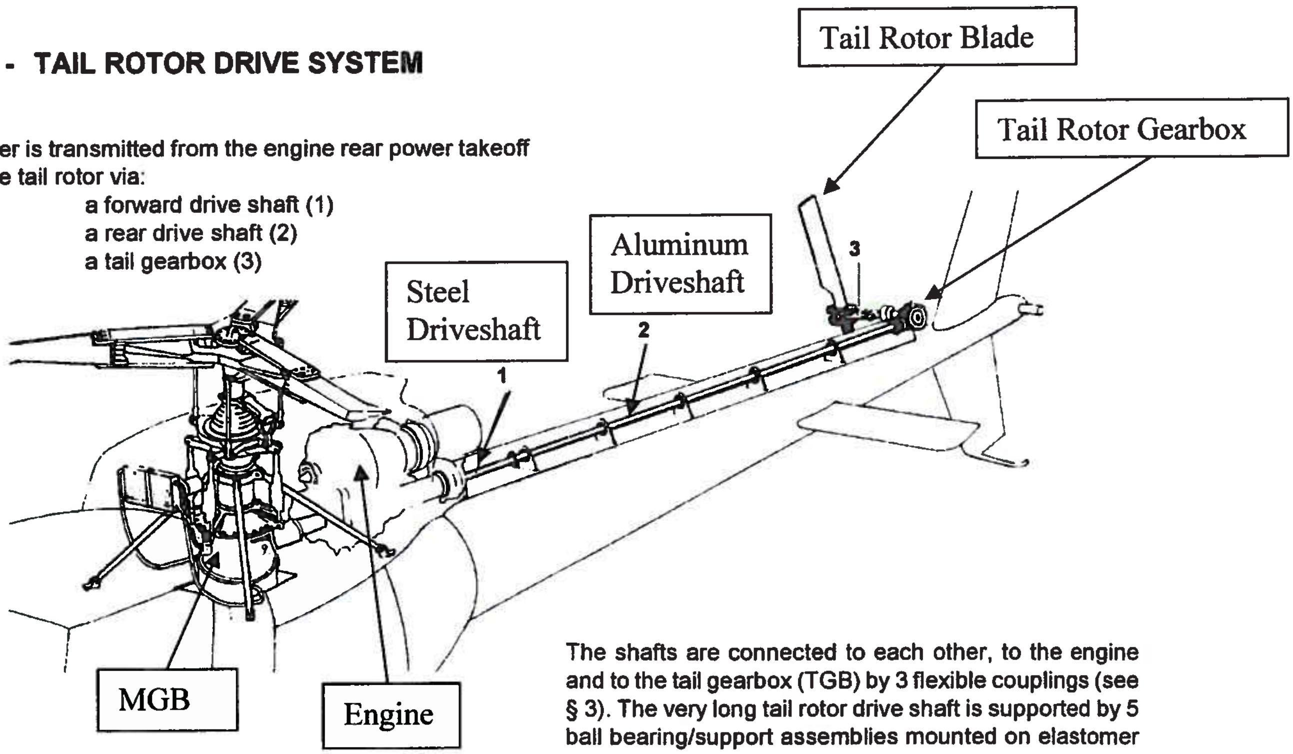


Figure 13

5.1 - TAIL ROTOR DRIVE SYSTEM

Power is transmitted from the engine rear power takeoff to the tail rotor via:

a forward drive shaft (1)
a rear drive shaft (2)
a tail gearbox (3)



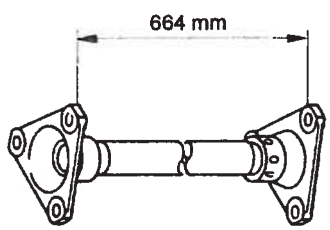
The shafts are connected to each other, to the engine and to the tail gearbox (TGB) by 3 flexible couplings (see § 3). The very long tail rotor drive shaft is supported by 5 ball bearing/support assemblies mounted on elastomer bushes that damp out the system vibration (viscoelastic "deflection and torsion" dampers).

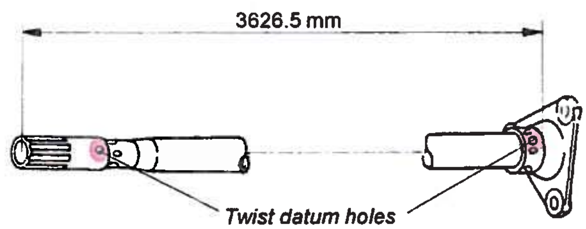
Figure 14

5.2 - TAIL ROTOR DRIVE SHAFTS (Cont'd)

The forward drive shaft is made of steel as it is located in a hot area under the engine exhaust nozzle.

As the rear drive shaft is long, it must be as light as possible and is therefore made of 1.6 mm thick dural.





NOTE:
Each flexible coupling on the forward shaft is secured by 3 bolts with balancing washers that form a matched assembly.

The tail rotor drive shaft is balanced (Refer to the Maintenance Manual for the balancing procedure).

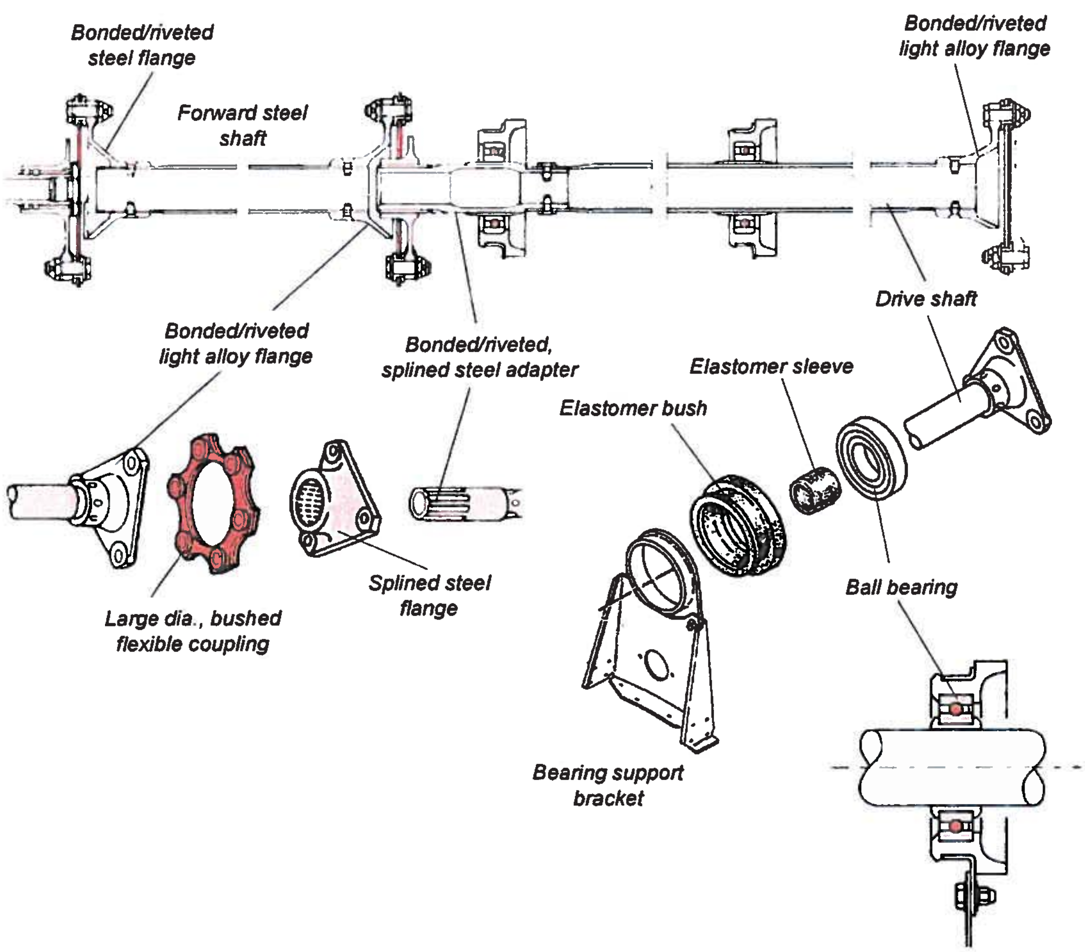


Figure 15

Figure 16

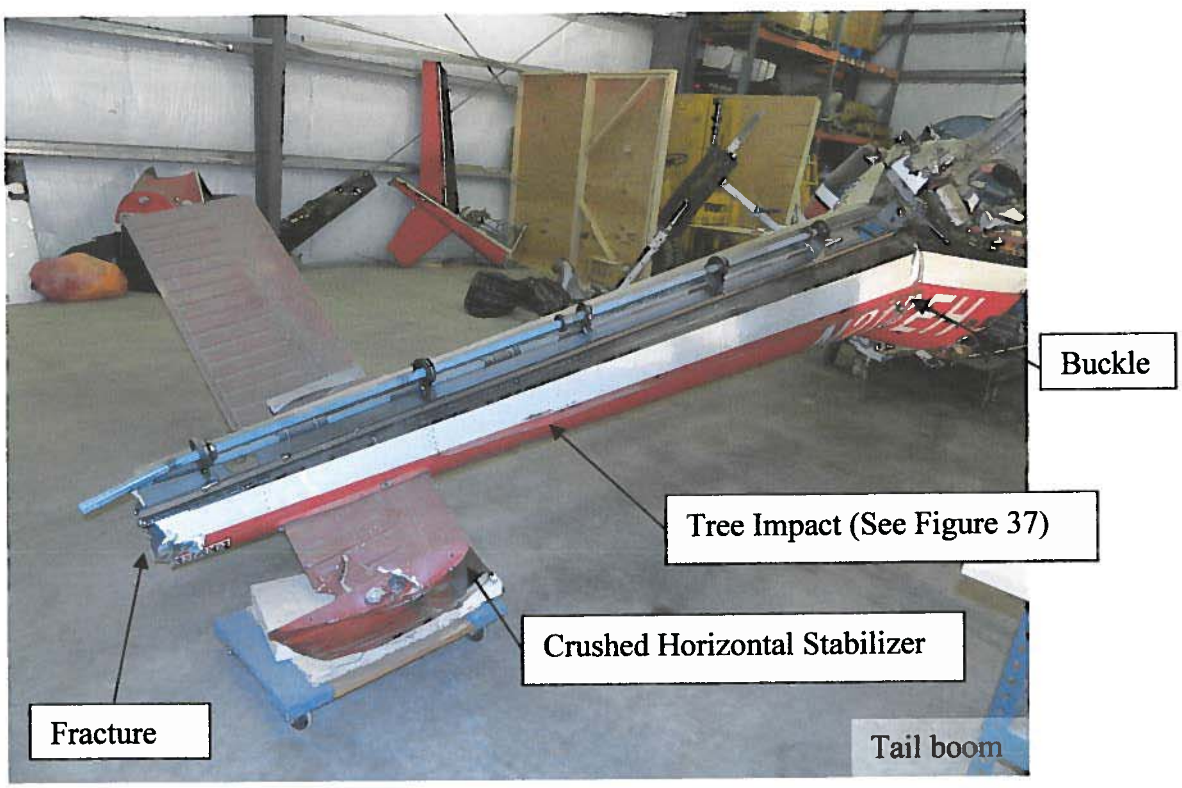


Figure 17

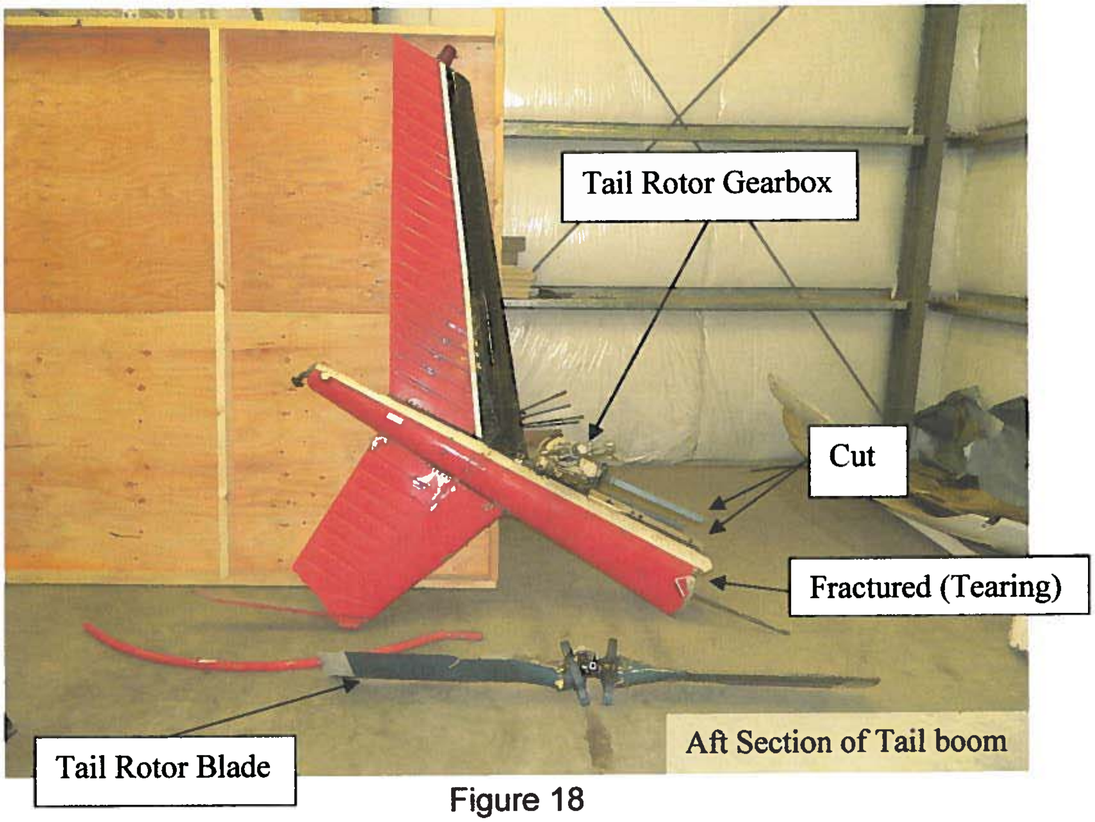
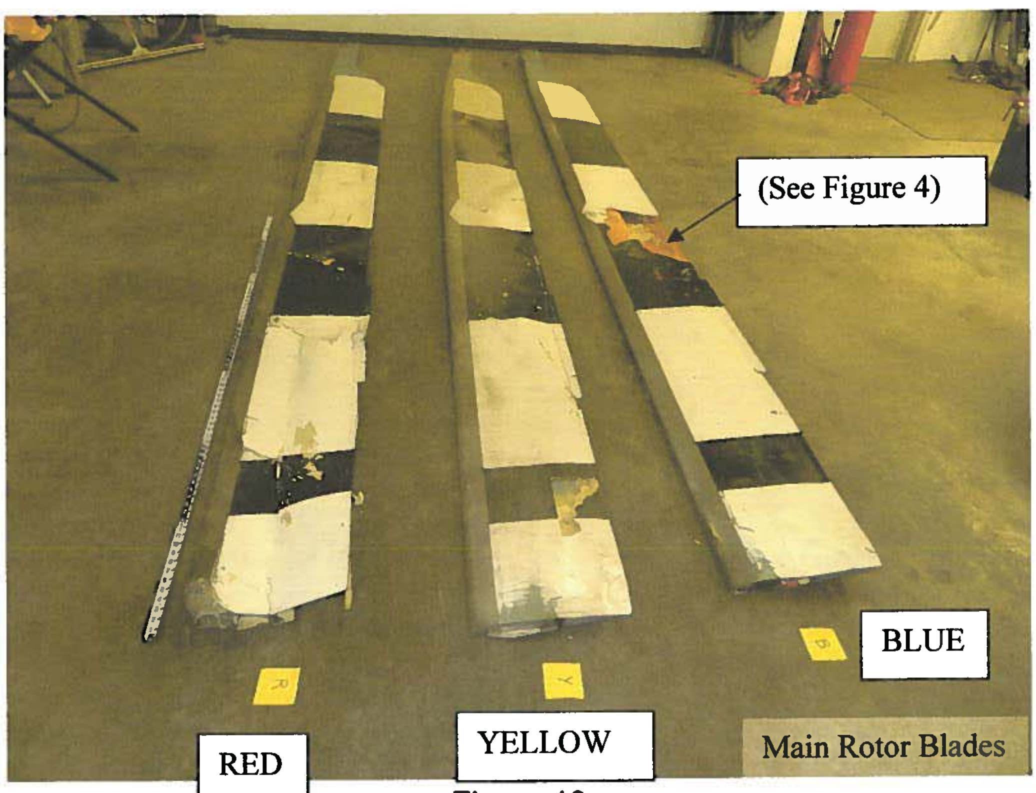


Figure 18



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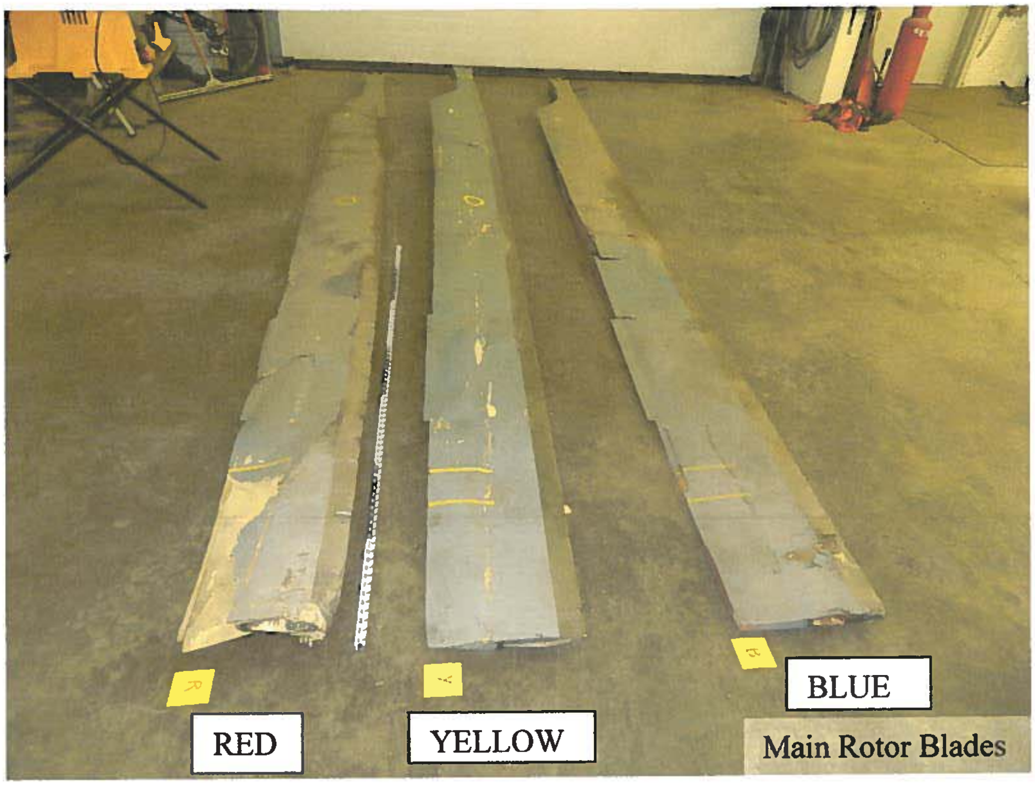


Figure 20

Figure 21

Figure 22

Figure 23

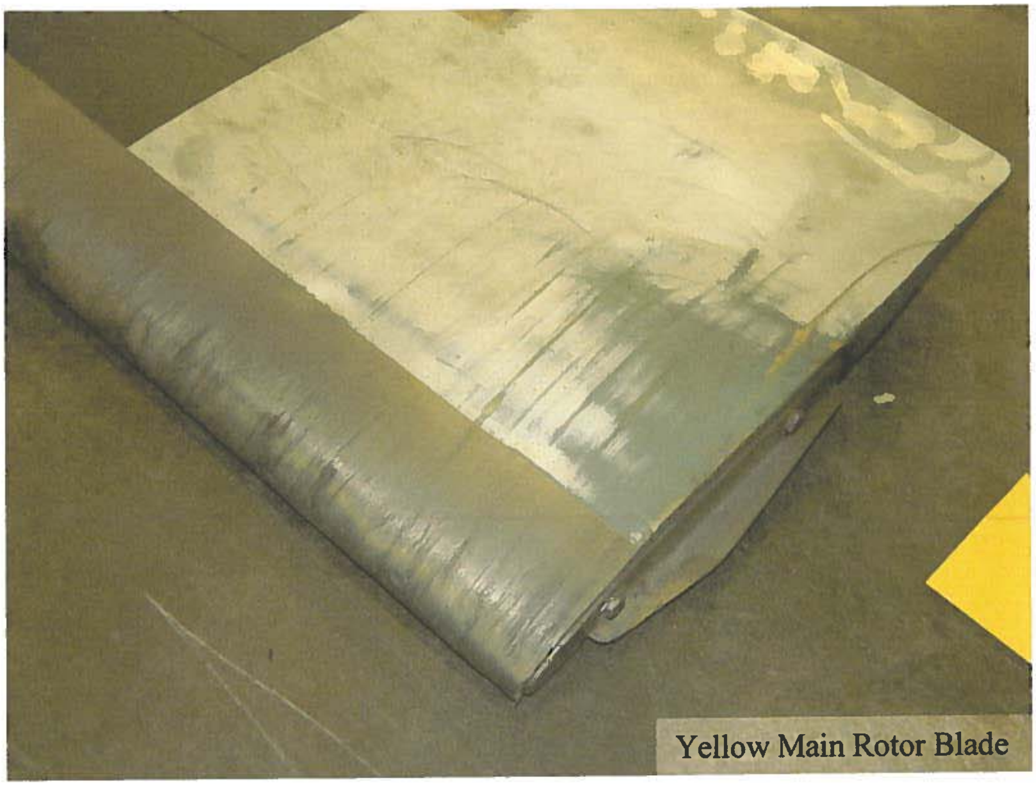


Figure 24

Figure 25

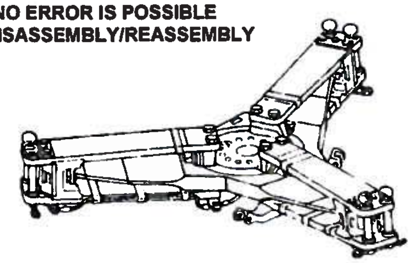
Figure 26

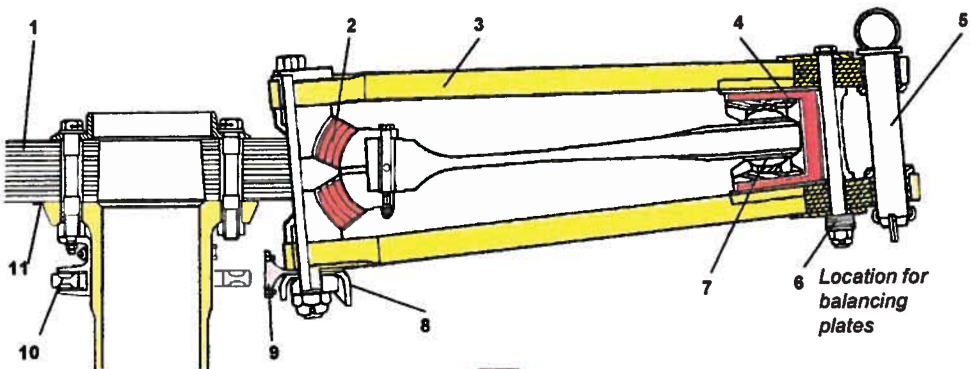
Figure 27

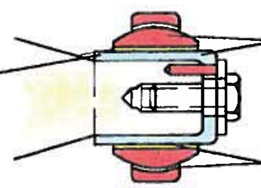
4.3.3. MRH COMPONENTS

1 - Star (glass-resin)
2 - Thrust bearing (laminated elastomer)
3 - Sleeve flange (glass-resin)
4 - Frequency adapter (3 elastomer layers)
5 - Blade attach pin
6 - Light alloy washers (replaced by balance weights, if necessary)
7 - Self-lubricating balljoint centered in bush
8 - Blade horn
9 - Thrust fitting (droop restrainer)
10 - Droop restraining ring
11 - Hub locating mounting pad

All the rotor hub parts are either perfectly symmetrical or foolproofed :
NO ERROR IS POSSIBLE IN DISASSEMBLY/REASSEMBLY

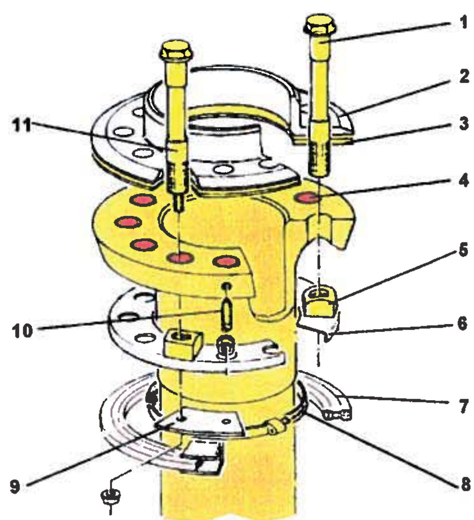






ROTOR HUB INSTALLATION ON ROTOR MAST

1 - Star attach bolt
2 - Flanged ring
3 - Anti-corrosion washer
4 - Bush
5 - Ring nut
6 - Retaining ring for nuts (5)
7 - Droop restrainer ring
8 - Clamp for stirrups (9)
9 - Stirrup for retaining ring (7)
10 - Stud for sleeve electrical bonding braid
11 - Bolt attaching star and stirrup (9)



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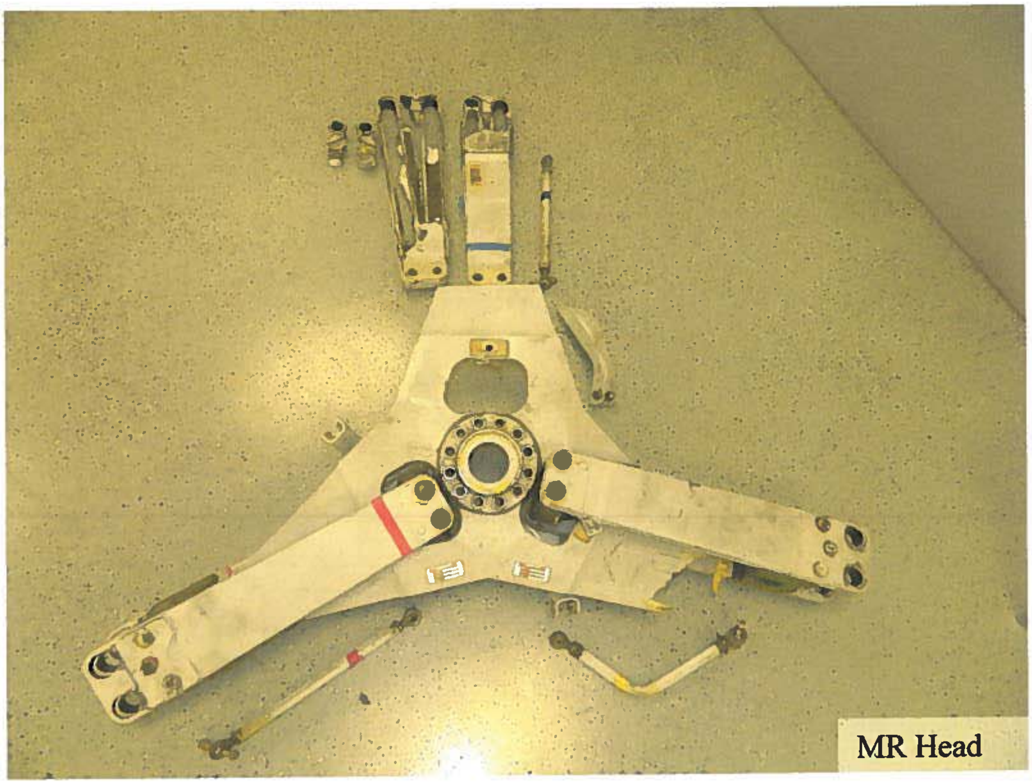

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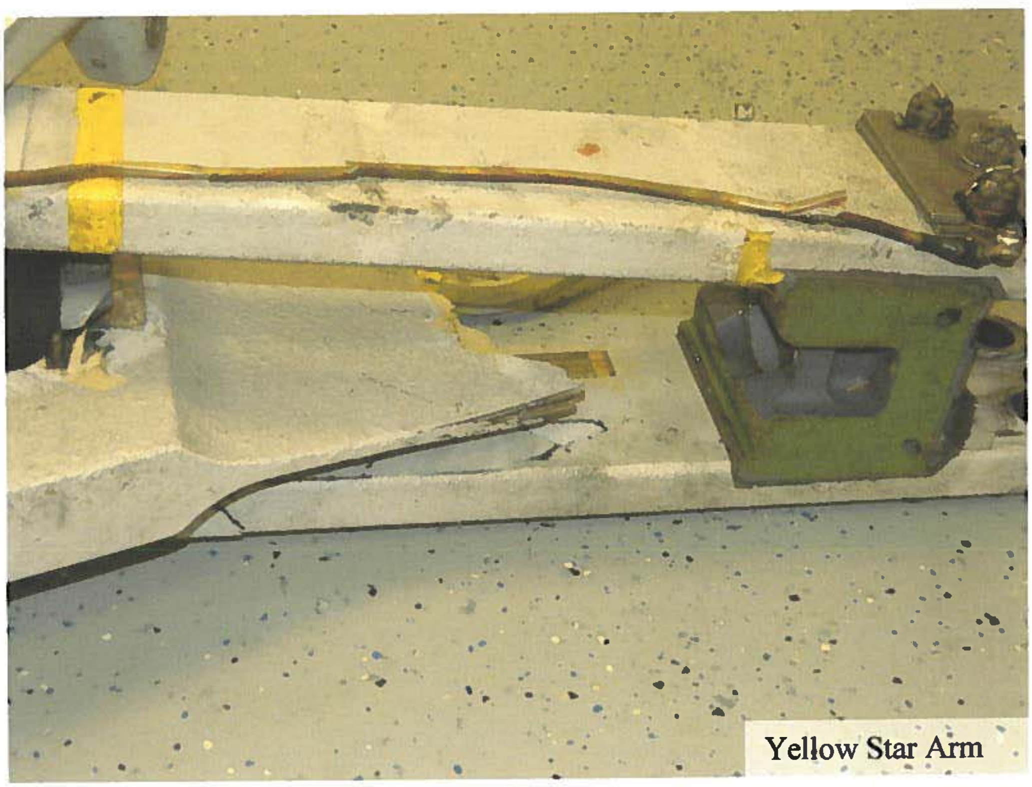

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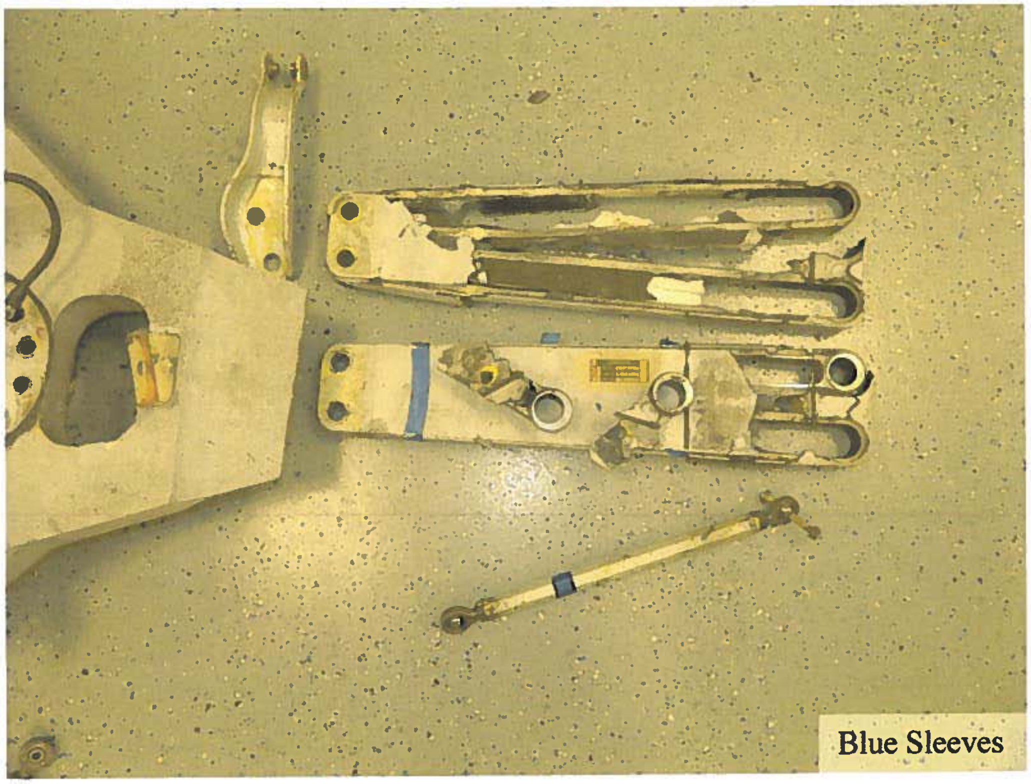


Figure 31

Figure 32

Figure 33

Figure 34

Figure 35

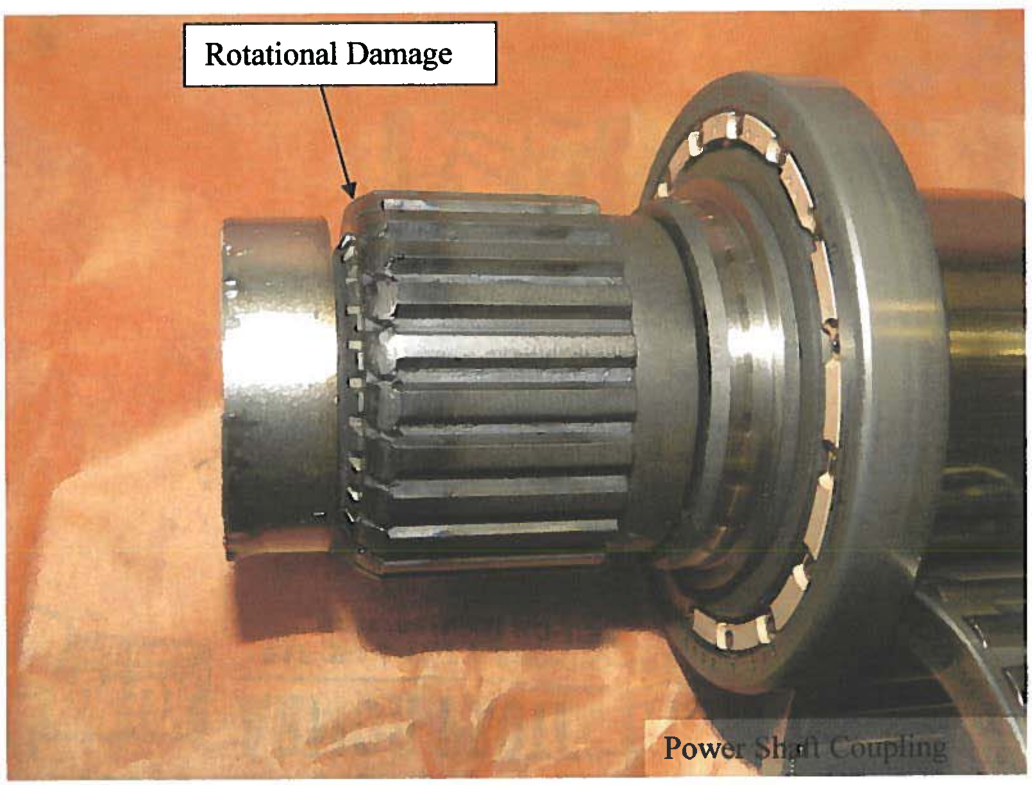


Figure 36

Figure 37

Figure 38

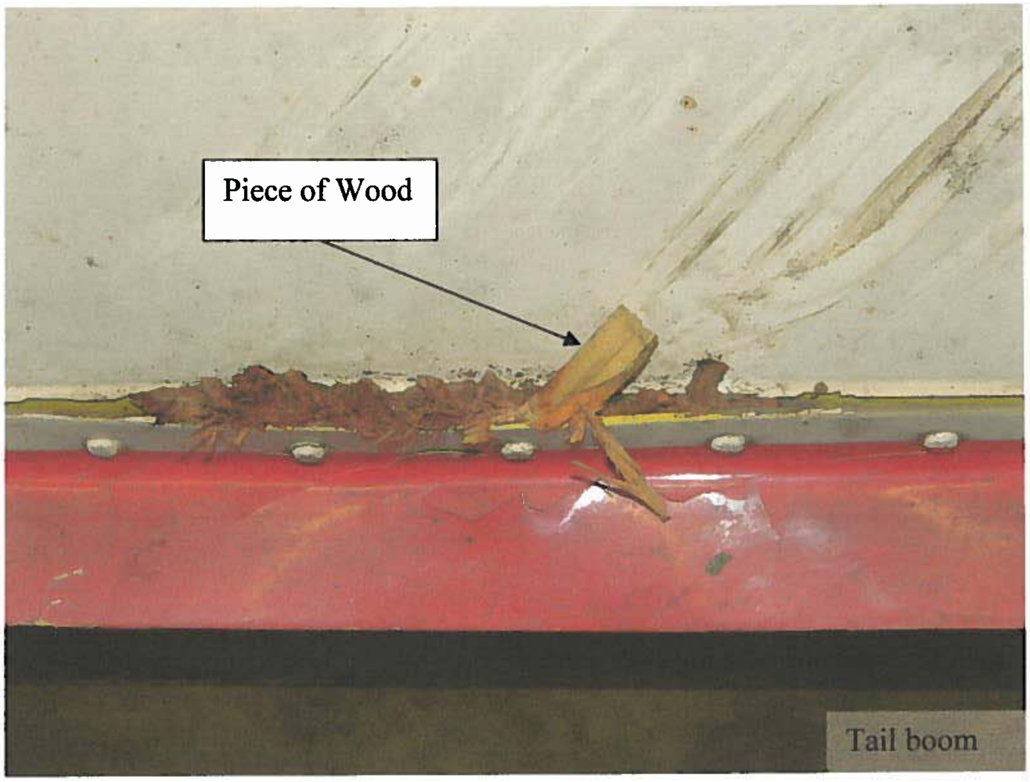
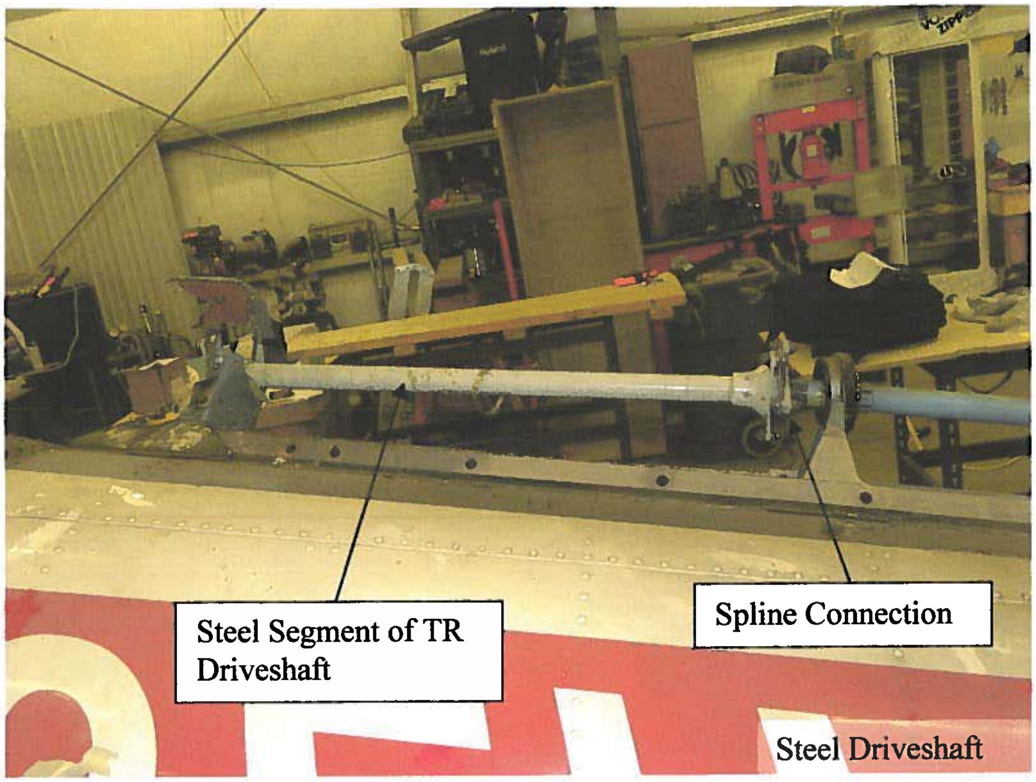


Figure 39

Figure 40



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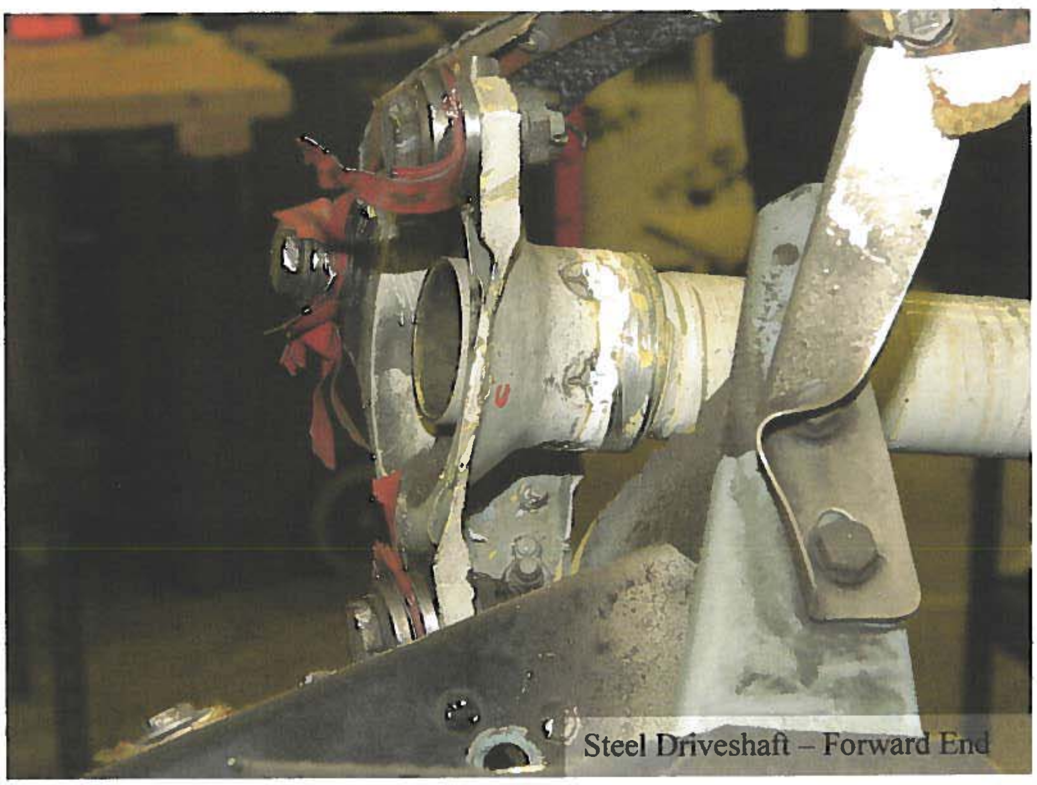

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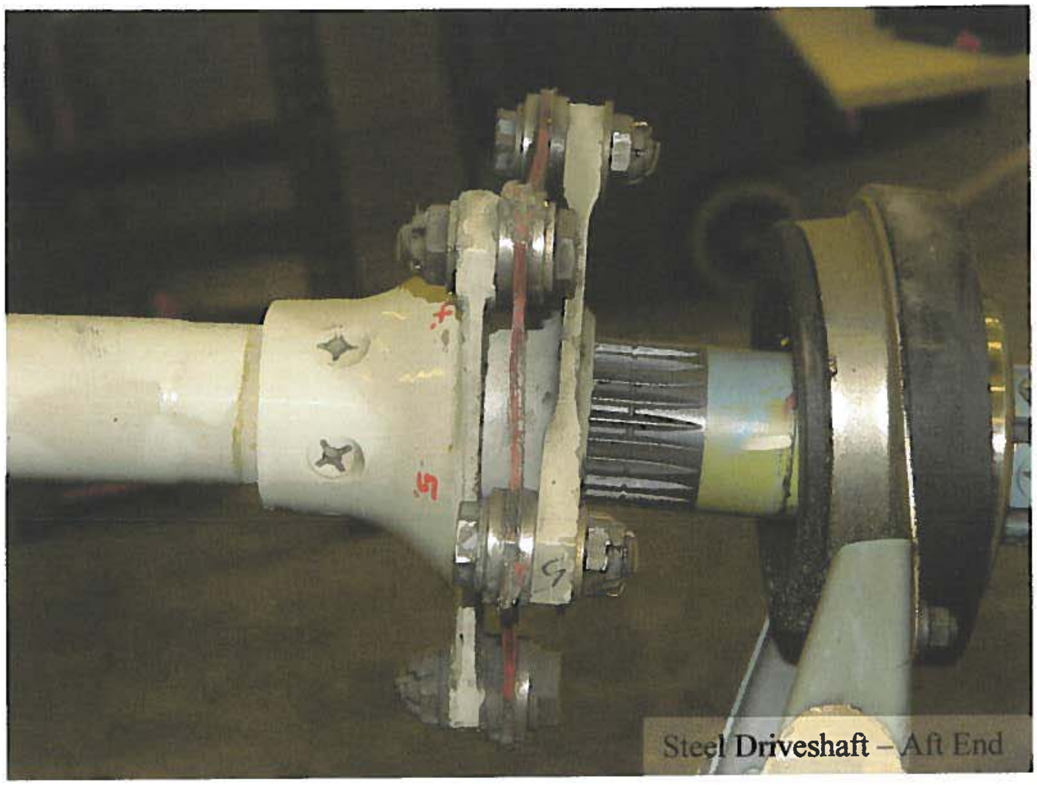

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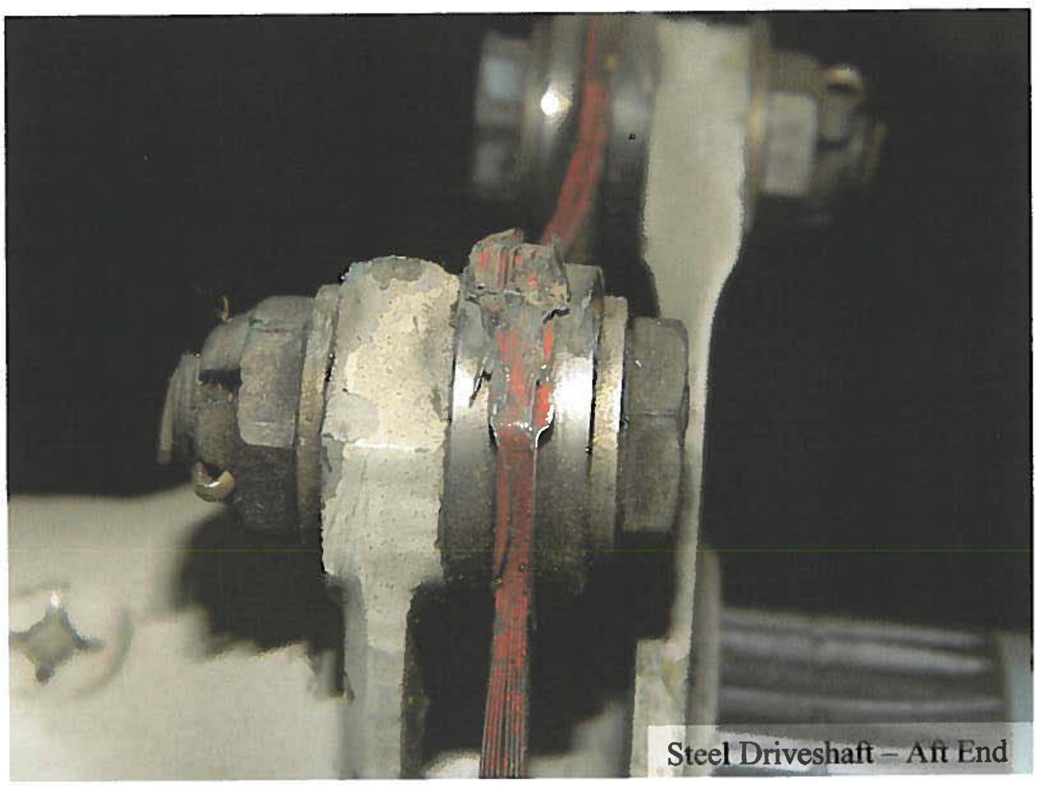


Figure 44

Figure 45

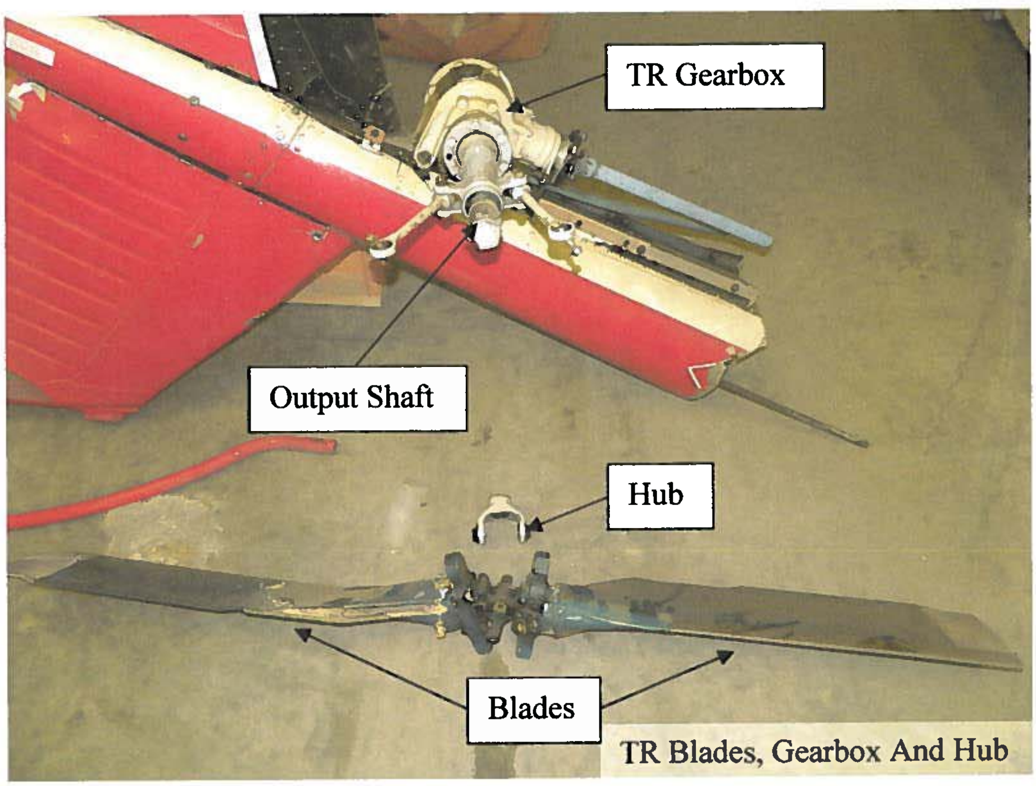
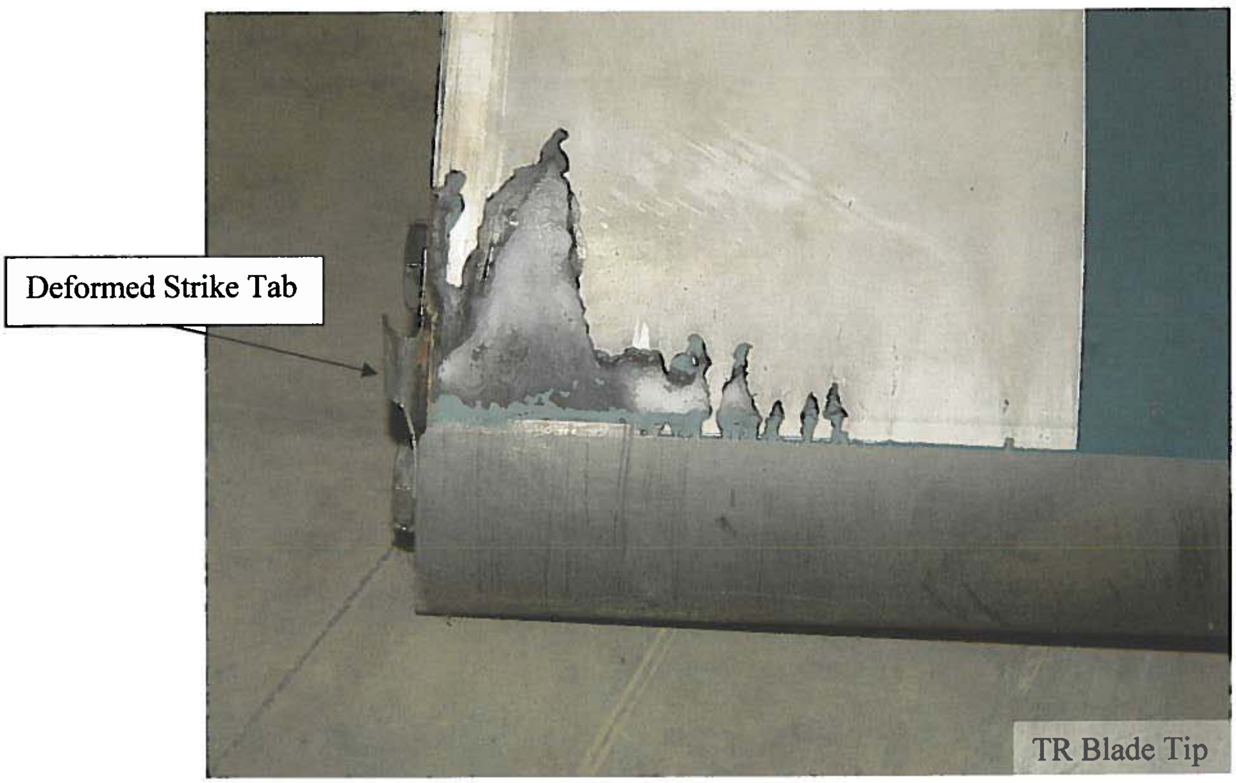


Figure 46

Figure 47



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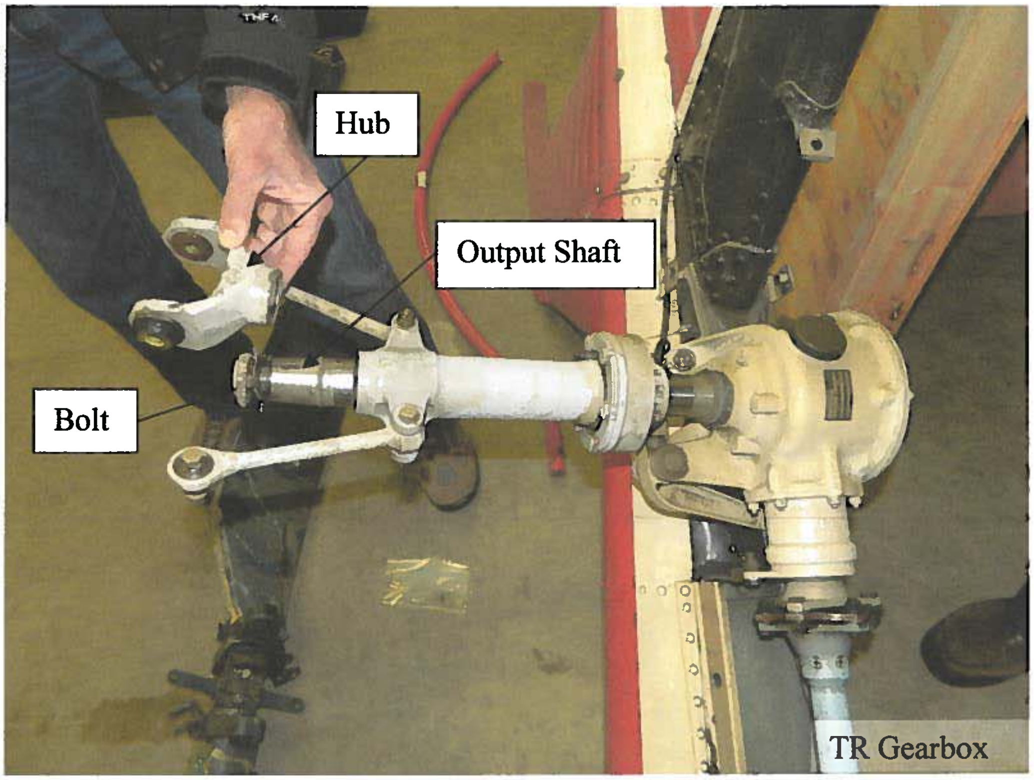

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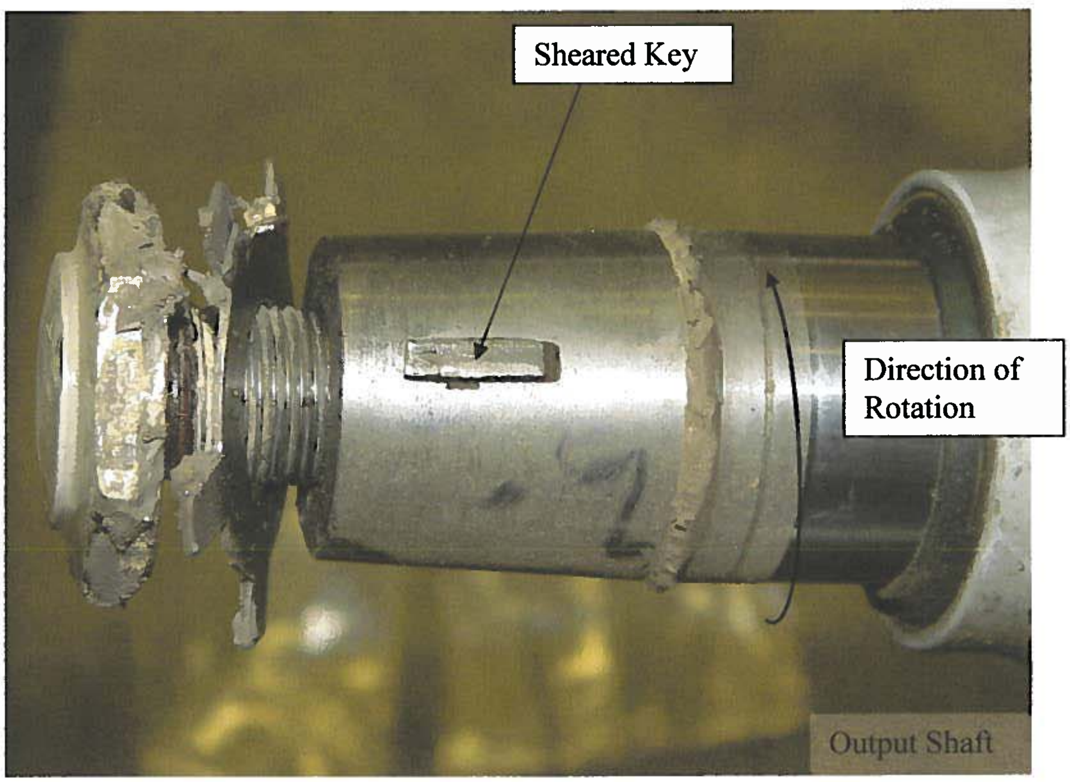

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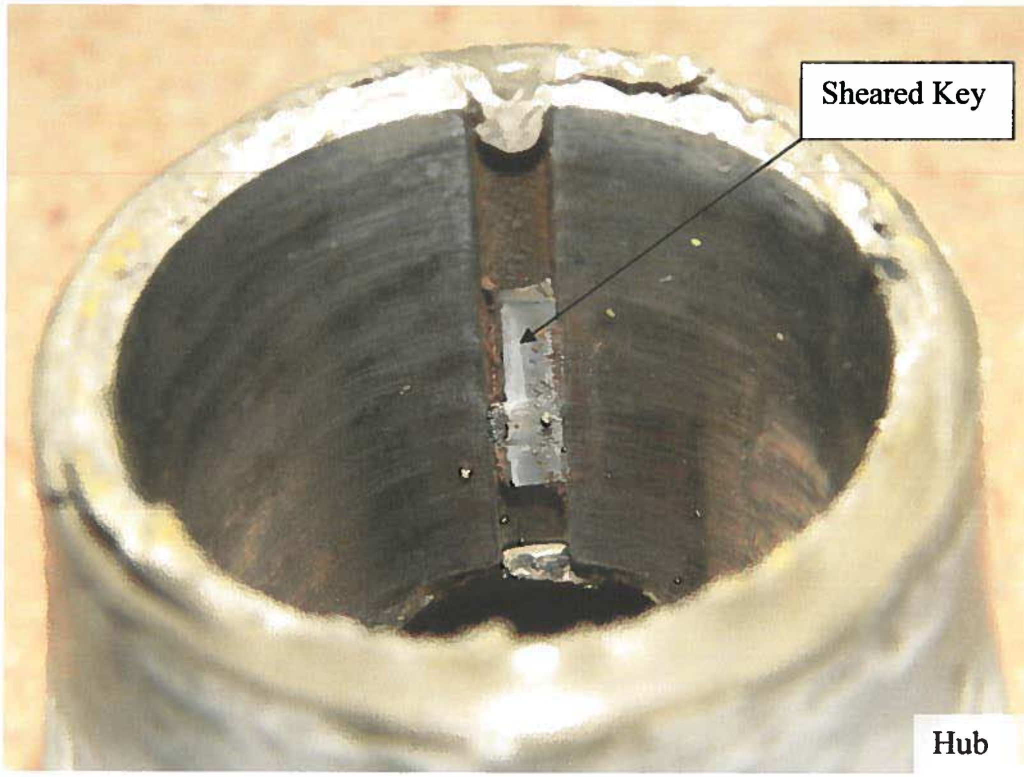
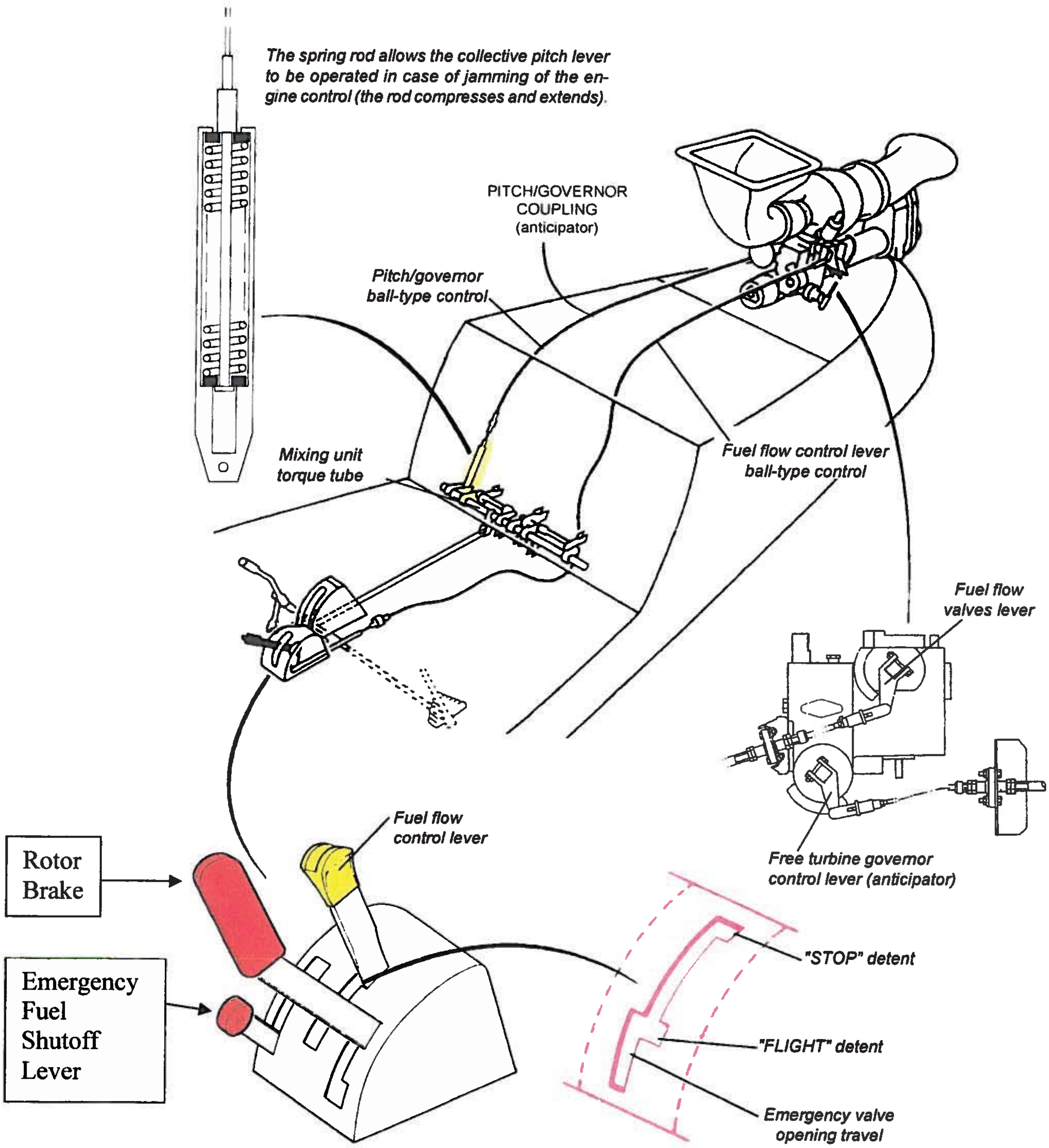


Figure 51

14.4.3. ENGINE CONTROL LINKAGE COMPONENTS AND THEIR LOCATION



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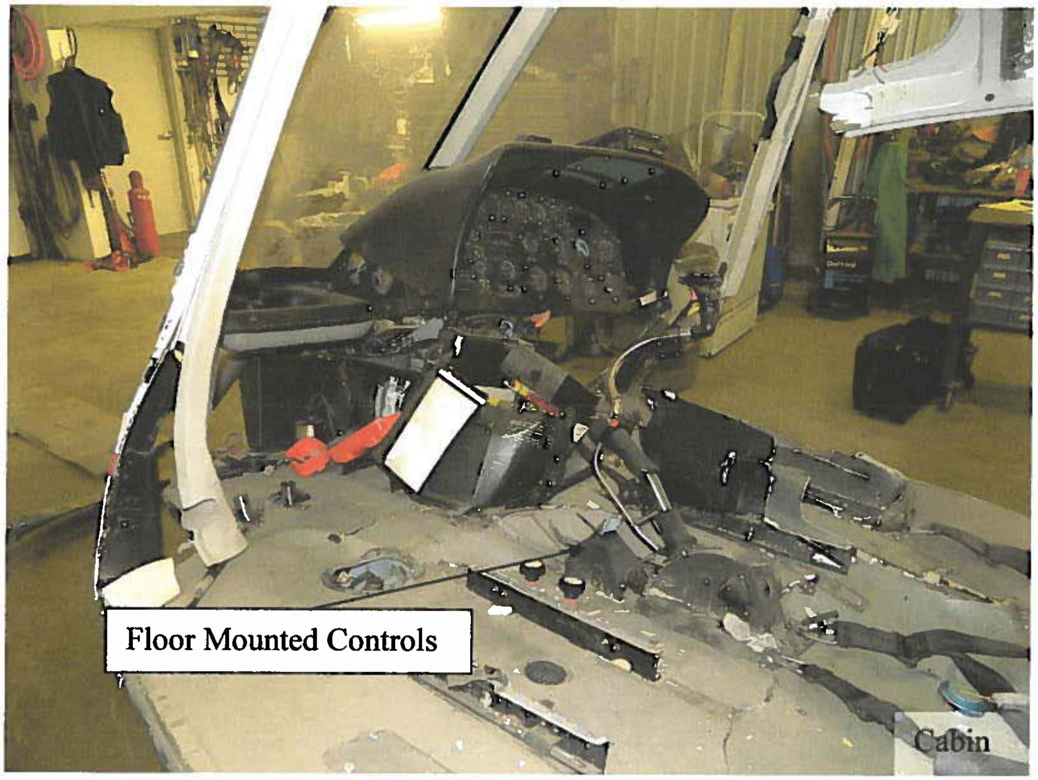

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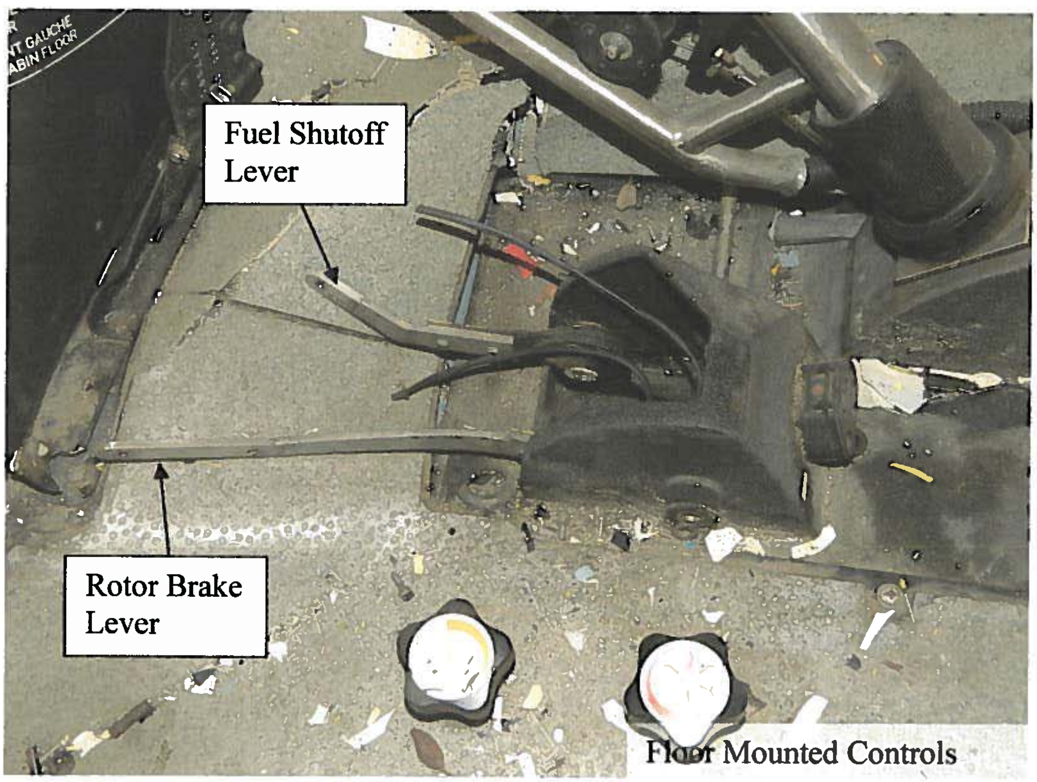

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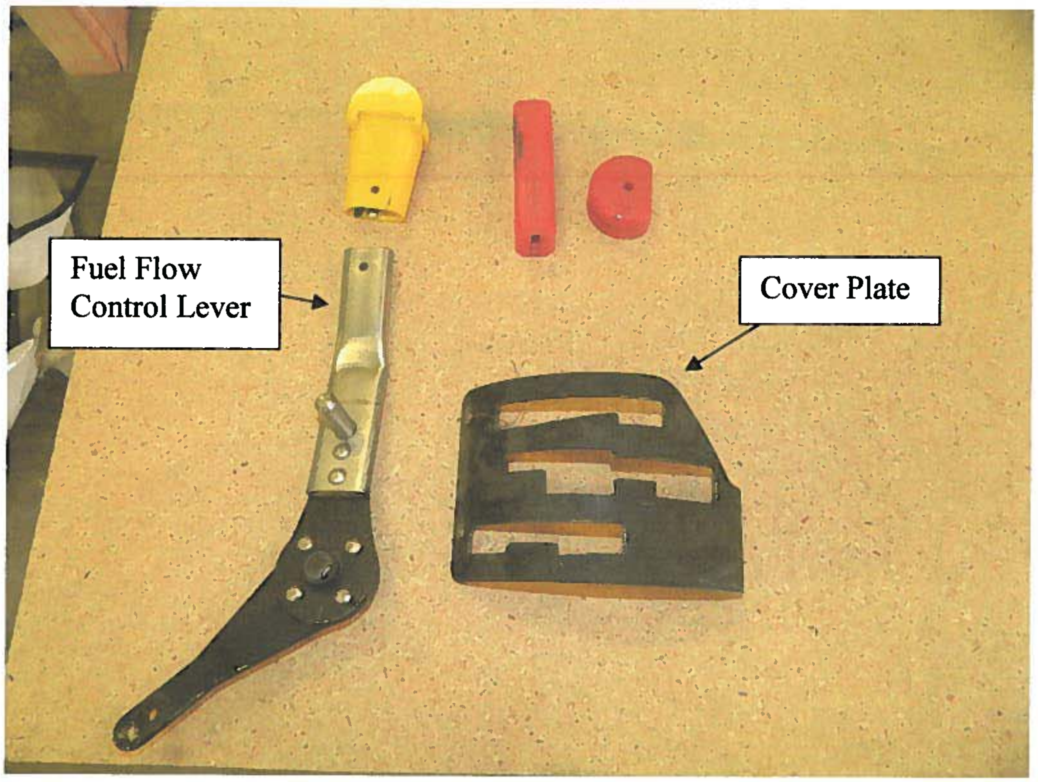

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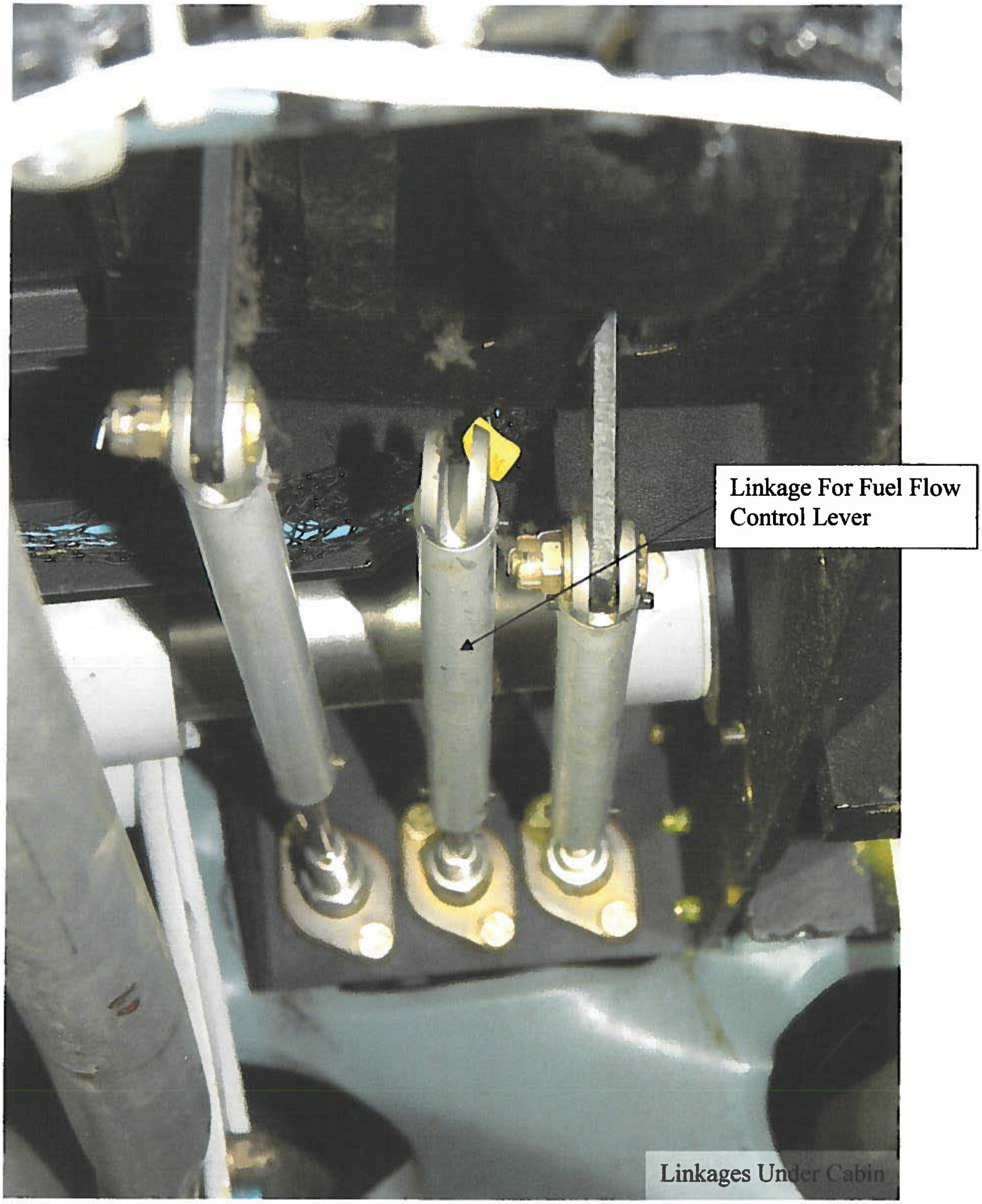


Figure 56

Figure 57

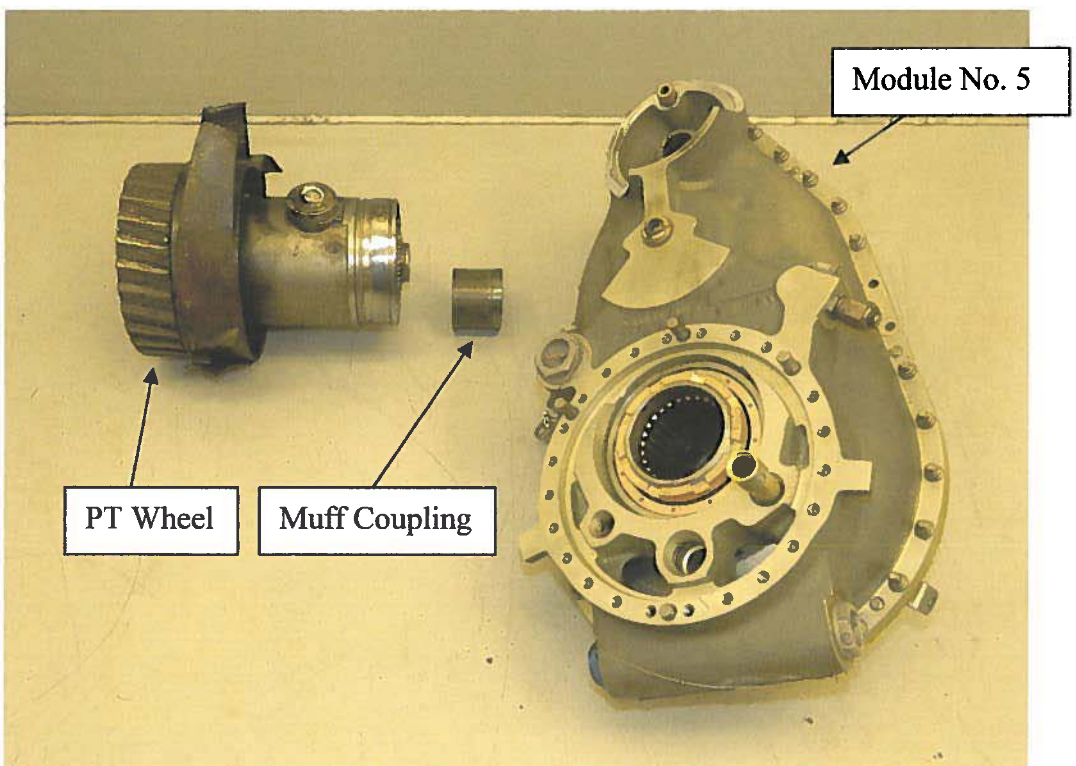


Figure 58

Figure 59

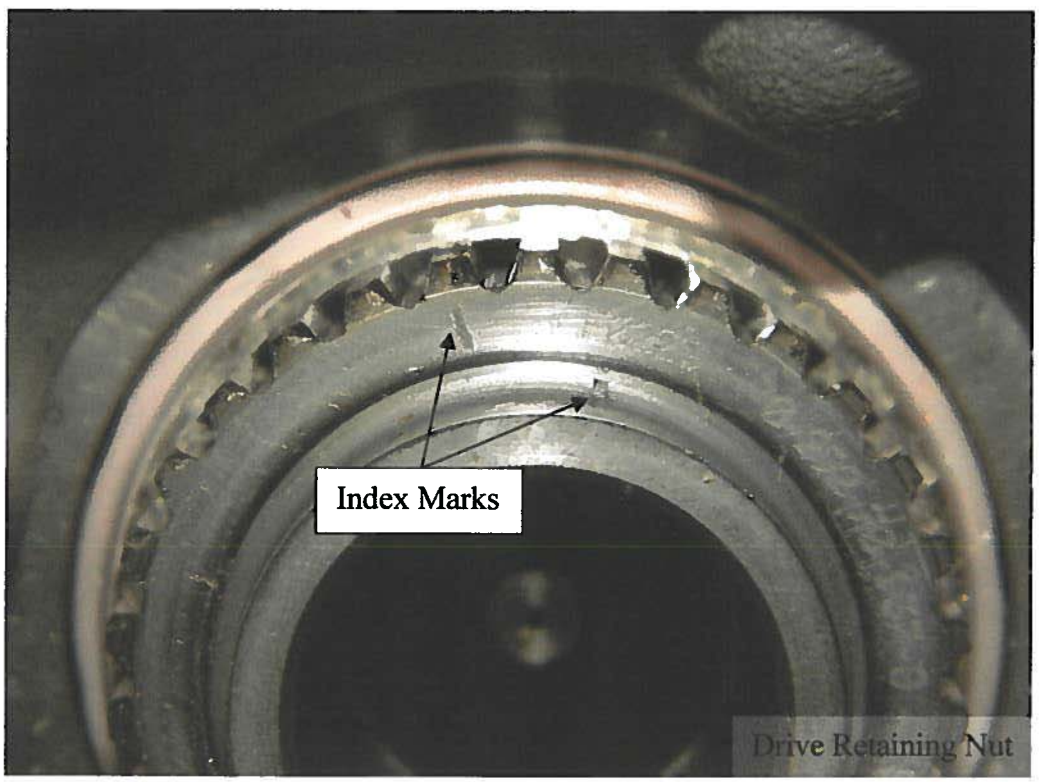


Figure 60

Muff Coupling

Figure 61

Muff Coupling Splines

Figure 62

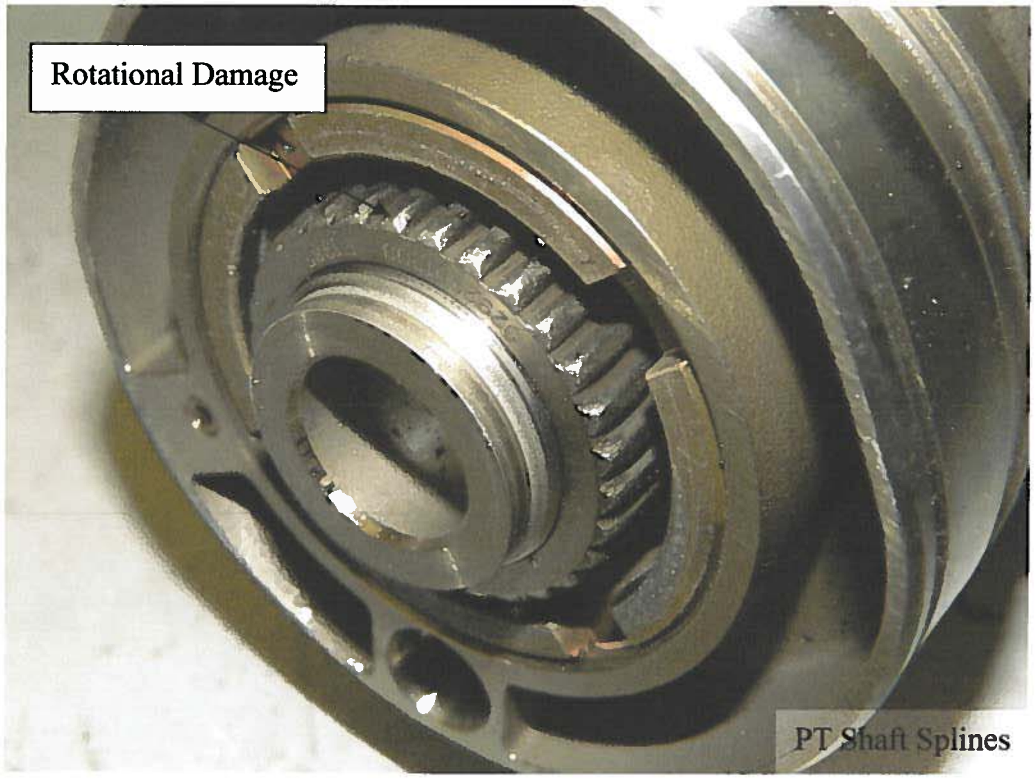
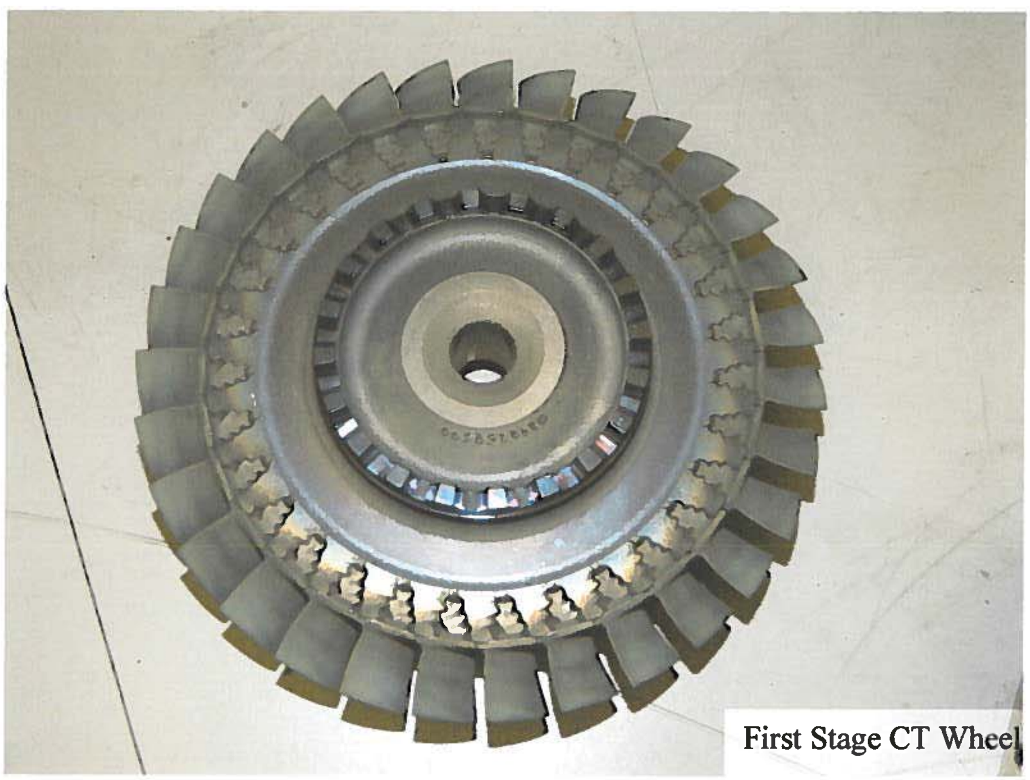


Figure 63



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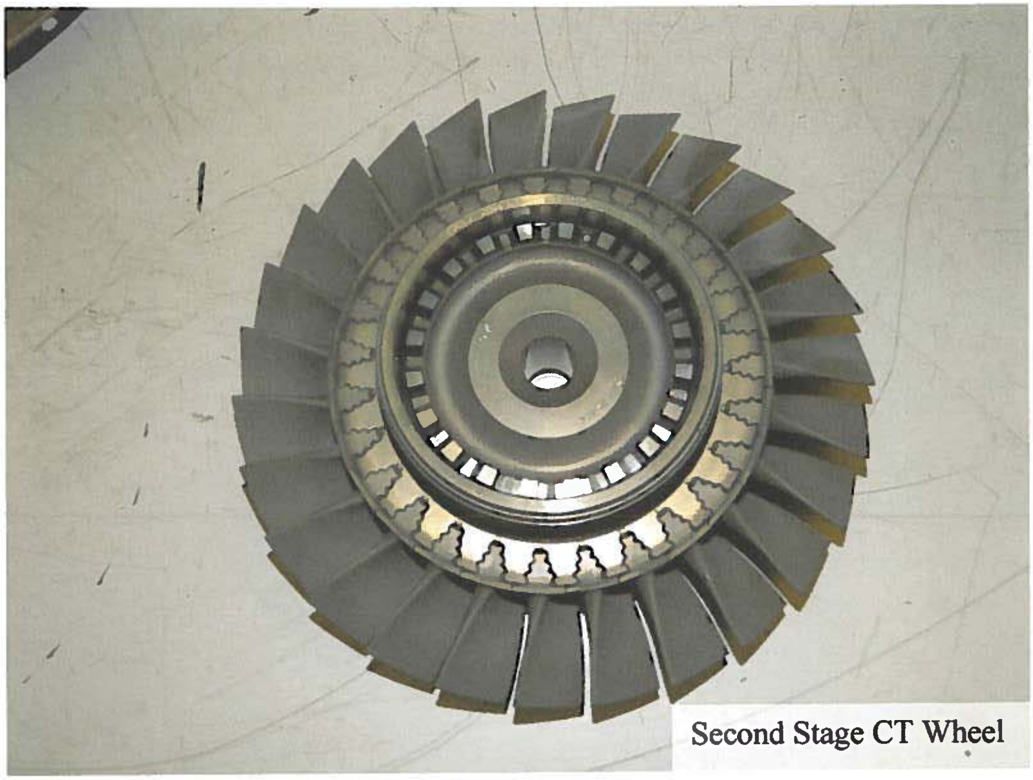

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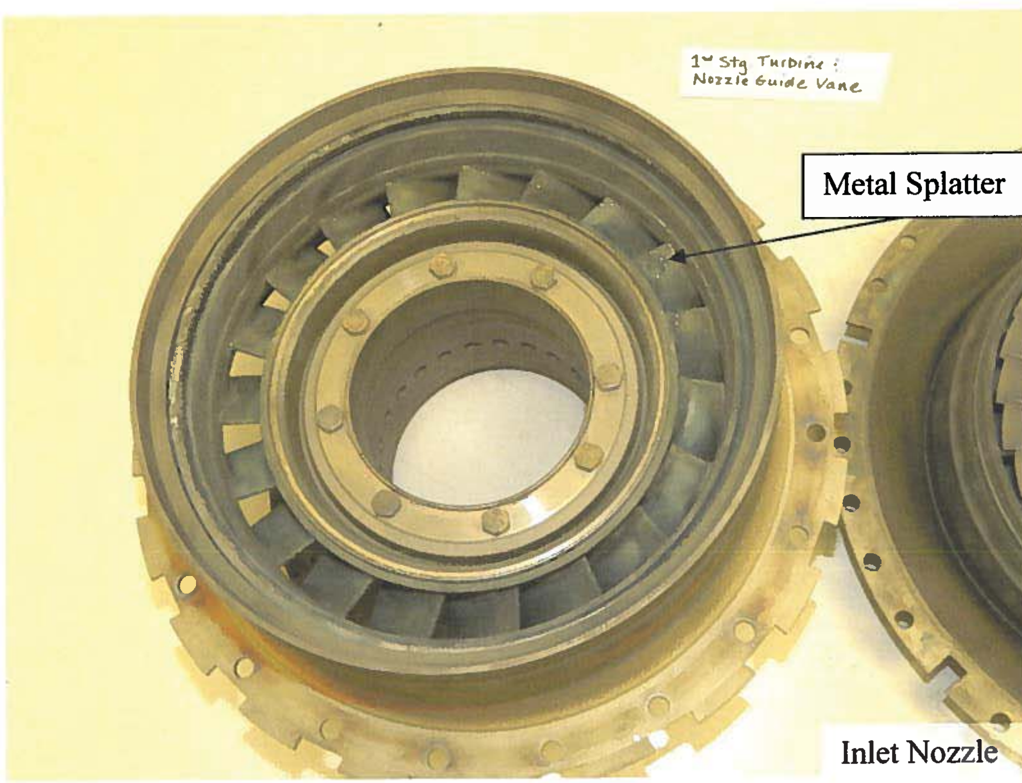

Figure 66

Figure 67

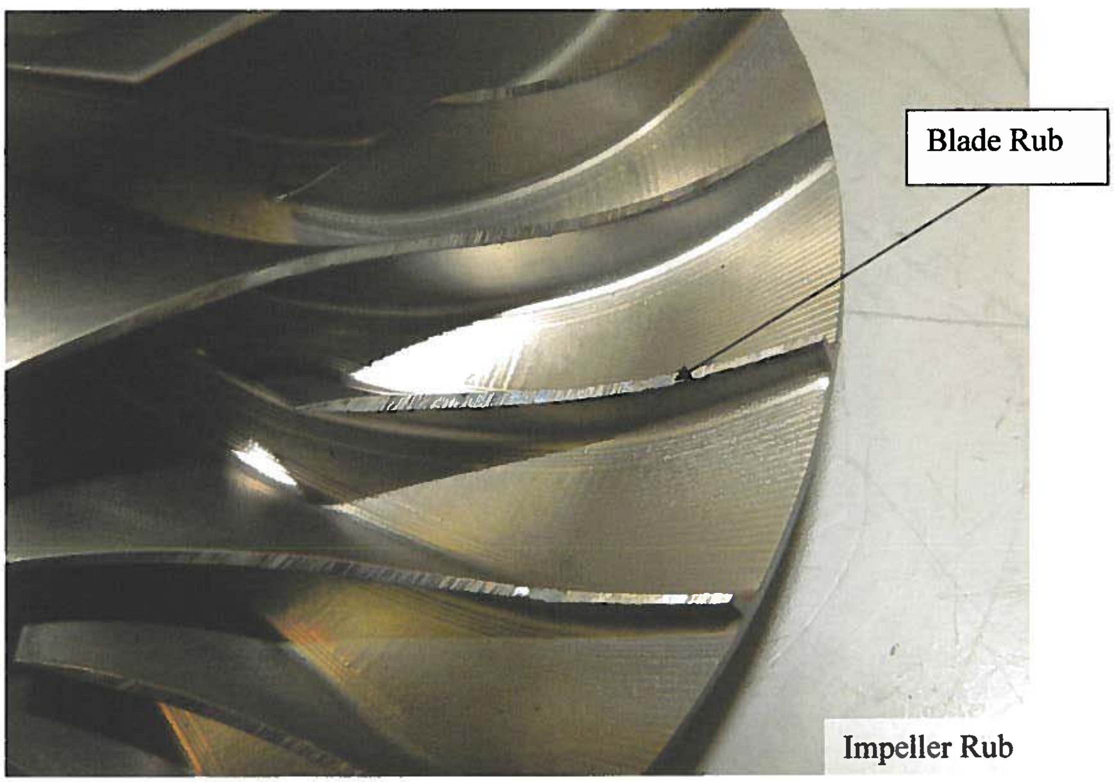

Figure 68

Figure 69

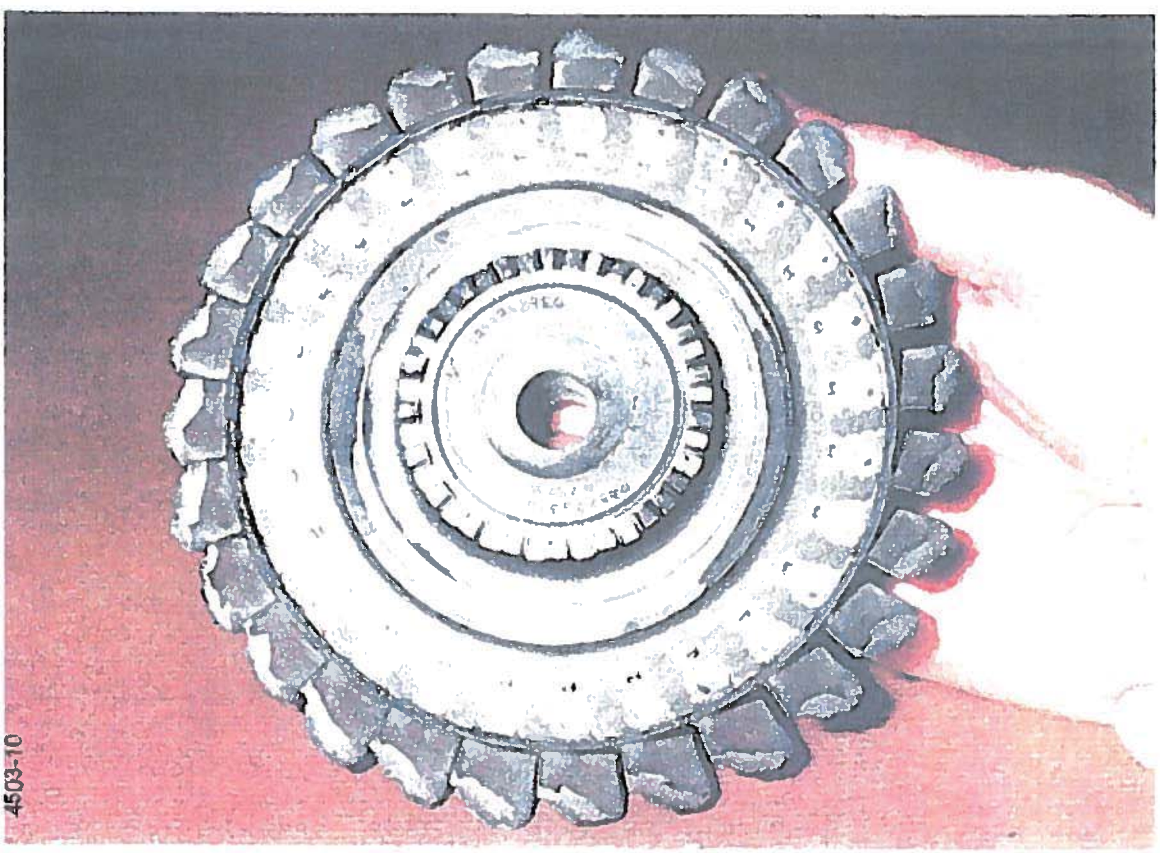

Figure 70

Appendix A

1. NTSB Factual Report Aviation, NTSB ID: ANC08FA053
2. Eurocopter's Petition for Reconsideration
3. NTSB Response to Petition for Recommendation
4. Turbomeca Engine Factual Report
5. Accident scene and helicopter photographs (FAA)
6. Accident scene and helicopter photographs (NTSB annotated)
7. Wreckage photographs (NTSB, Turbomeca, American Eurocopter)
8. Photographs of the engine (engine examination)
9. Photographs of the MGB (transmission examination)
10. Photographs from Weather Cameras
11. Photographs taken by L. Cunningham of engine disassembly on October 23, 2012
12. Photographs of sheared key from TR hub and driveshaft
13. Photographs of exemplar fuel control lever
14. Eurocopter drawing of engine-to-MGB driveshaft
15. Liberty Mutual's Expert Disclosures
16. Report by Doug Stimson
17. Turbomeca Maintenance Manual
18. AS350 Instruction Manual
19. Deposition testimony and exhibits of Q. Ellington, B. Certain, Y. Nicolas, M. Soulhiard and L. Cunningham
20. NTSB report DEN00FA084 (Blanding, Utah accident), Turbomeca Investigation Report, American Eurocopter report, and photographs